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Alternative Technical Subplans. Areawide Waste Treatment Plan for the Greater Houston Area (Section 208, P.L. 92-500)

Houston-Galveston Area Council, TX

Prepared for

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ALTERNATIVE TECHNICAL SUBPLANS

DECEMBER 1977

HOUSTON-GALVESTON AREA COUNCIL

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ALTERNATIVE TECHNICAL SUBPLANS

AREAWIDE WASTE TREATMENT MANAGEMENT PLAN
FOR THE
GREATER HOUSTON AREA
(SECTION 208, PL 92-500)

DECEMBER 1977

PREPARED FOR THE HOUSTON-GALVESTON AREA COUNCIL
BY ROY F. WESTON, INCORPORATED

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P R E F A C E

In order to estimate costs and other characteristics of sewer collection and treatment systems, it is necessary to make estimates of future service areas, treatment plant locations, lift stations and trunk line layouts. These locations and configurations are estimated for preliminary planning purposes and should be considered as approximate rather than specific. Accordingly, the locations and configurations presented within this report are not specific requirements of the plan. The exact location and sizing of sewer collection/treatment system elements will be determined for a given service area when a detailed engineering study is done either as part of the 201 facility plan or as part of the preliminary engineering study undertaken independently of the grant program. Appropriate changes in the recommendations of this report will be made at that time as necessary to reflect actual conditions for the area.

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CHAPTER I - INTRODUCTION

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CHAPTER I - INTRODUCTION

The primary objectives of this Activity are to develop, evaluate, and recommend alternative technical methods for achieving water quality criteria during critical stream conditions. The costs associated with the control strategies are defined in order to allow for a comparison of the alternatives.

This report utilizes and is partially based on extensive background information and analytical tools developed in other portions of the Areawide Waste Treatment Management Plan - Greater Houston Area 208 Program. The most extensively utilized outputs are:

1) Water quality criteria for stream segments within the 208 planning area.
2) Water quality data base.
3) Interim land use and population projections.
4) Steady-state and nonsteady-state water quality simulation models.
5) Point source inventory of municipal and industrial dischargers.
6) Municipal and industrial wasteload projections.
7) Point source control strategies including costs and impacts.
8) Nonpoint source wasteload identifications and projections.
9) Nonpoint source control strategies including costs and impacts.

In order to obtain the final technical plan most beneficial to the 208 Planning Area, alternatives are developed for both the dry weather and wet weather critical conditions. Dry weather alternatives are based on three regionalization concepts for municipal point source wasteloads. The three regionalization concepts are then developed along various treatment themes for controlling

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wasteloads to the stream; e.g. increasing treatment efficiency, removal of wasteloads through transport or land application techniques. Each concept is not presented for each theme.

Through this approach, many basic alternatives are presented and the review/selection process has at its disposal a wide range of choices. The selection process allows evaluation of themes and concepts independently with no constraints on applying alternative themes to regionalization concepts, even if that combination was not included in the initial presentation of alternatives.

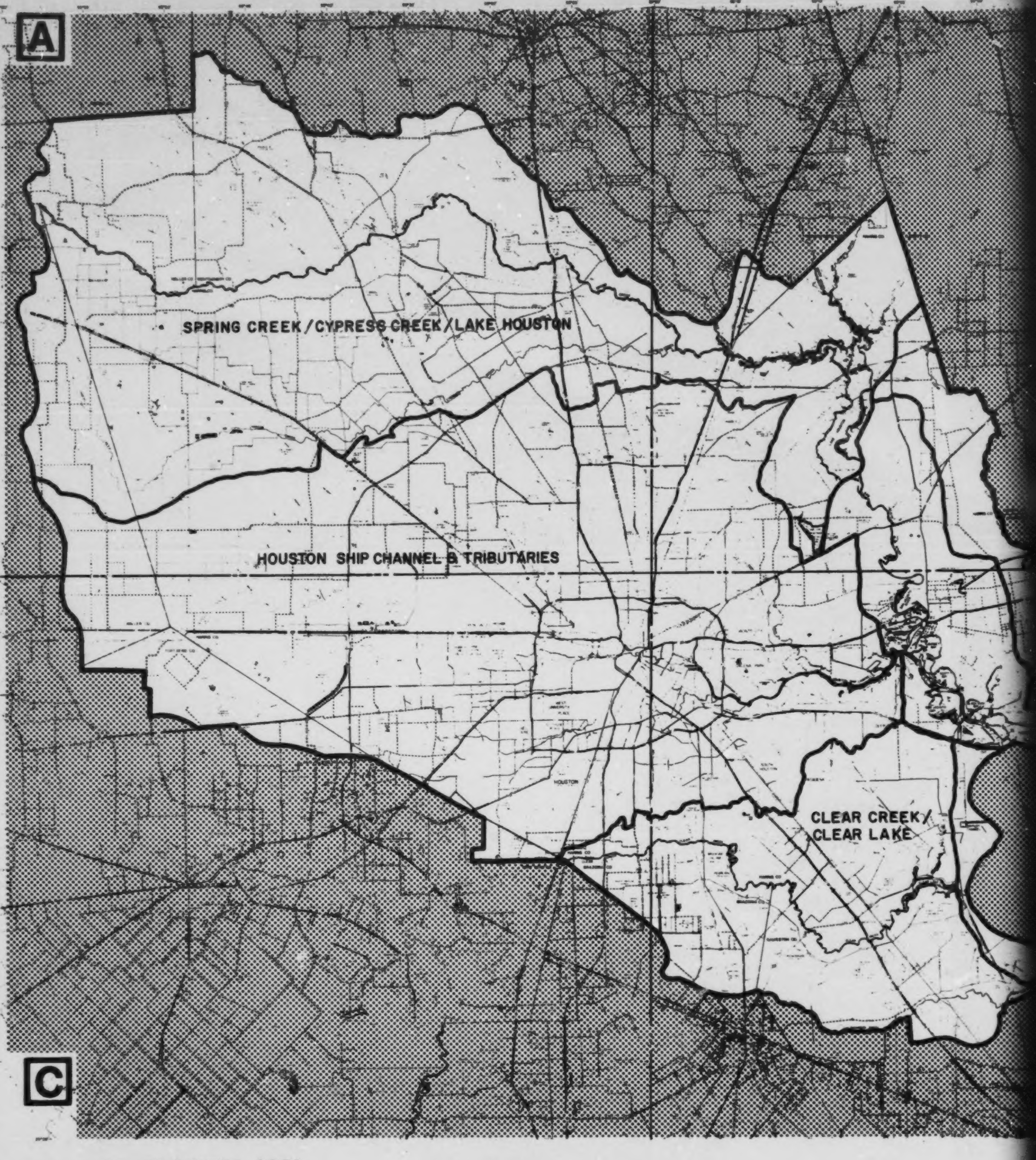
Since major portions of the basic input data are based on future projections and unverified information, which is often the situation in an areawide plan, in many cases the alternatives present a macroscopic picture of the planning area. For example, population projections may indicate the total treatment capacity required within a major land area. However, specific locations for the facilities providing this capacity are dependent on the relatively volatile projections of disaggregated land use. When this is the case, total capacities are presented without indication of specific location.

Information contained herein is presented first in a Methodology chapter which includes the basic assumptions and analyses utilized throughout the subplan development activity. Next, alternative technical subplans are presented for four hydrologically defined areas, which are shown in Exhibit I-1:

1) Spring Creek/Cypress Creek/Lake Houston.
2) Clear Creek/Clear Lake, including Armand Bayou and Dickinson Bayou.
3) Houston Ship Channel and tributaries to confluence with the San Jacinto River.
4) Lower San Jacinto River and Houston Ship Channel below confluence with the San Jacinto River.

Each subplan is evaluated for its major impacts including cost, energy utilization, land utilization, and environmental effects. Additionally, its reliability and sensitivity are evaluated.

Technical review and public participation are incorporated into the evaluation and selection of the preferred alternative technical subplan and its impacts. This process forms the basis for final plan selection.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SPRING CREEK/CYPRESS CREEK/LAKE HOUSTON
HOUSTON SHIP CHANNEL & TRIBUTARIES
CLEAR CREEK/
CLEAR LAKE
HOUSTON
C

— 208 PLANNING AREA
— DRAINAGE BASINS

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A	B
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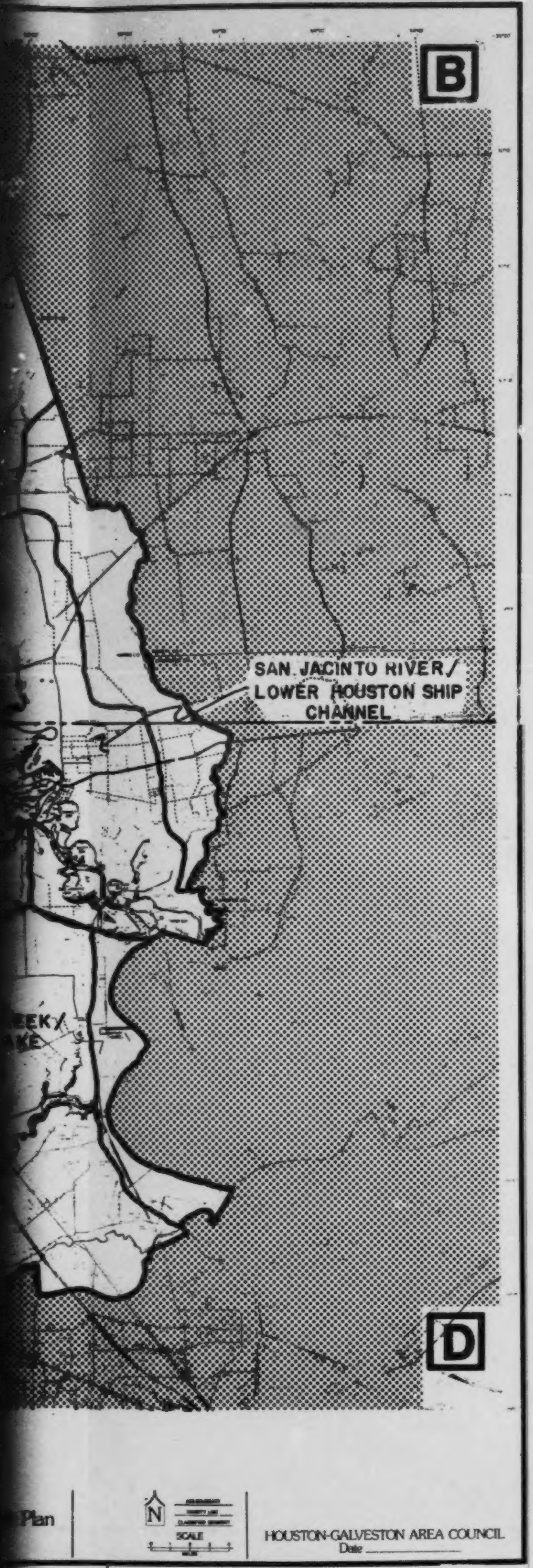
Areawide Waste Treatment Management Plan
HOUSTON AREA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Date

GREATER HOUSTON 208 PROGRAM
HOUSTON-GALVESTON AREA COUNCIL

DESIGNATED PLANNING AREA

DRAWN BY: ROY F. WESTON	REVISIONS BY:	EXHIBIT I-1
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CHAPTER II - METHODOLOGY

CHAPTER II - METHODOLOGY

Segment Analysis Methodology - Dry Weather

General

The dry weather segment analysis is a first level evaluation of the stream. Dry weather wasteloads entering a stream during defined critical conditions are evaluated to determine if the desired water quality will be obtained.

Any problem areas within the stream are identified and allowable loadings are determined for each level of water quality. The method for achieving the allowable wasteloads is developed in the alternative technical subplans.

The inputs and defined critical conditions for the dry weather segment analysis are presented within this section.

Point Source Wasteloads

Industrial. Industrial wasteloads for 1995 are presented in the Point Source Analysis. The projected loadings are based upon Best Practicable Control Technology effective in 1977 and Best Available Technology effective in 1983.

The industrial wasteload projections are distributed according to subbasin and Standard Industrial Classification (SIC) number. In the segment analysis, industrial wasteloads are allocated throughout the subbasin at existing industrial locations.

Municipal. The projected municipal wasteloads for 1995 are developed on the assumption that existing and future population centers will be served by municipal sewage treatment facilities. Flows for existing and future service areas within the City of Houston were obtained from the 1995 municipal projections contained in the Point Source Analysis report.

Flows and wasteloads for the fringe and outlying areas of the City of Houston are developed by disaggregating projected population on a census tract by census tract basis to single family and multi-family areas according to the 1995 land use projections contained in Population and Land Use, Interim Projections for the Areawide Waste Treatment Management Plan, July 1976.

Based upon this methodology, the 1995 population served by municipal treatment systems are allocated to each stream basin as shown in Table II-1.

Population centers not presently served by municipal treatment systems are either incorporated into existing adjacent systems or are designated as new conceptual service areas. Flows for these population centers are assumed to be 100 gallons per capita per day.

An estimation of population is made only for the purpose of approximating discharges into the stream from potential point sources outside of existing areas. The remaining scattered residential areas are allocated to septic tank wasteloads. Septic tank wasteloads are discussed later in this section.

The municipal point source wasteloads generated by each sewage treatment facility are based upon the effluent sets listed in Table II-2 as defined by the Texas Department of Water Resources (TDWR). An initial effluent set is assigned to municipal dischargers in classified segments according to the recommendations of the wasteload evaluation reports prepared by the TDWR. Unclassified segments are initially evaluated at effluent set 2. The effluent set utilized for the initial evaluation of a stream segment is defined as the existing level of technology for that particular stream segment.

In conformance with the TDWR wasteload allocation methodology and the Houston Area Steady State Modeling Reports, ammonia-nitrogen concentrations of 8.0 mg/l, dissolved oxygen levels of 4.0 mg/l, fecal coliform concentrations of 200 MPN/100 ml, and temperatures of 85°F are the assumed effluent conditions. A list of effluent sets initially applied to each stream segment is contained in Table II-3.

Nonpoint Source Wasteloads

Nonpoint source wasteloads are developed for septic tanks, dredging activities, and benthal demand. No other dry weather nonpoint source wasteloads are available for the segment analysis.

Septic Tank. Septic tanks wasteloads are developed from data contained in Chapter II of the Nonpoint Source Analysis report. Since the Nonpoint Source Analysis report was prepared without the benefit of alternative technical subplans, the population allocated to septic tank treatment systems was assumed to be greater than that developed for the segment analysis and the alternative technical subplans. For this reason, a unitizing factor is developed

TABLE II-1

1995 POPULATION SERVED BY MUNICIPAL TREATMENT SYSTEMS BY BASIN

Stream Basin/Segment Number	1995 Population[1]
Spring Creek (1008)	72,000
Cypress Creek (1009)	118,000
Lake Houston (1002)	41,000
Clear Creek - Nontidal (1102)	88,000
Clear Creek - Tidal (1101)	38,000
Clear Lake (2425)	60,000
Armand Bayou	55,000
Dickinson Bayou - Nontidal (1104)	2,000
Dickinson Bayou - Tidal (1103)	29,000
Houston Ship Channel (1005, 1006, 1007)	176,000
San Jacinto River - Tidal (1001)	21,000
White Oak Bayou	242,000
Buffalo Bayou	781,000[2]
Brays Bayou	460,000
Sims Bayou	668,000[3]
Vince Bayou	108,000
Hunting Bayou	38,000
Greens/Halls Bayou	210,000
Carpenters Bayou	6,000
	3,213,000

[1] Values based on data reported in the Point Source Analysis Municipal Projections.

[2] Northside Plant shows decrease in served population over planning period and no population projections are available for the 69th Street plant. Therefore, value is probably low.

[3] Sims Bayou Plant shows decrease in served population. Therefore, value is probably low.

TABLE II-2

TDWR EFFLUENT SETS

Effluent Set	Level of Treatment (mg/l)				Treatment Process Corresponding to Effluent Set
	BOD	TSS[1]	NH_3-N	P	
0	30	30[2]	-	-	Oxidation Ponds
1	20	20	8[3]	-	Secondary (conventional design)
2	10	15	8[3]	-	Modified secondary (enhanced solids separation)
3	5	10	8[3]	-	Set 2 with chemical addition
4	5	5	8[3]	-	Set 3 with filters
2N	10	15	5	-	Set 2 with biological nitrification
3N	5	10	5	-	Set 3 with biological nitrification
4N	5	5	3	-	Set 4 with biological nitrification
3P	5	10	8[3]	2	Chemical addition in biological process
4P	5	5	8[3]	1	Chemical precipitation after biological process

1. It should be noted that the value of TSS does not impact directly on water quality simulations as undertaken for the study. The solids do increase effluent BOD, NH_3-N, and P and may increase benthic demand in the stream. Departures from effluent TSS levels as compared to the defined effluent set should be considered on a case-by-case basis.

2. This value presently undergoing change due to EPA policy change on oxidation pond effluents.

3. This value not defined by TDWR as a part of "Policy for Effluent Standards". However, TDWR has utilized these values during waste load allocations.

TABLE II-3

EFFLUENT LIMITATIONS BY STREAM

Segment Number	Stream	30-Day Average BOD$_5$ mg/1	30-Day Average TSS mg/1	30-Day Average NH$_3$-N mg/1	30-Day Average P mg/1
1008	Spring Creek	10	15	8*	-
1009	Cypress Creek	10	15	5	-
1002	Lake Houston	5	10	5	-
1102	Clear Creek - Nontidal	5	12	5	2
1101	Clear Creek - Tidal	5	12	5	2
2425	Clear Lake	5	12	5	2
—	Armand Bayou	5	12	5	2
1104	Dickinson Bayou - Nontidal	20	20	8*	-
1103	Dickinson Bayou - Tidal	10	15	8*	-
1005	Houston Ship Channel	10	15	8*	-
1006	Houston Ship Channel	10	15	8*	-
1007	Houston Ship Channel	10	15	8*	-
1001	San Jacinto River - Tidal	10	15	8*	-
—	White Oak Bayou	10	15	8*	-
—	Buffalo Bayou	10	15	8*	-
—	Brays Bayou	10	15	8*	-
—	Sims Bayou	10	15	8*	-
—	Vince Bayou	10	15	8*	-
—	Hunting Bayou	10	15	8*	-
—	Greens/Hall Bayou	10	15	8*	-
—	Carpenters Bayou	10	15	8*	-

* These values are not standards but are estimates consistent with those utilized by TDWR during wasteload allocations.

for BOD and fecal coliform for each basin. This is obtained by dividing the total wasteload within each basin by the total population contributing to the wasteload, resulting in a per capita contribution which can be assigned to the new population allocated to septic tank systems in the alternative technical subplans. The wasteload factors developed for each basin are listed in Table II-4.

Septic tank wasteloads are input to the stream simulation model based on the land use projections. Since flow information associated with the septic tank wasteloads is not available, an assumed flow of 0.1 cfs is assigned to each stream junction receiving septic tank wasteloads.

Dredging. Dredging loads are developed from data contained in Chapter IV of the Nonpoint Source Analysis report. Average pollutant loadings due to dredge spoil disposal for channels subject to dredging are presented in the Nonpoint Source Analysis. These data are combined with information concerning the frequency, length, and volume of dredging in a particular channel to estimate the total daily wasteload occurring during dredging activities.

The average daily wasteload contribution from dredging activities in the 208 area is presented in Table II-5.

TABLE II-5

AVERAGE DREDGING WASTELOADS

	HSC	Clear Creek
BOD (lbs/day)	8600	1800
TKN (lbs/day)	300	70
PO_4 (lbs/day)	540	110

Benthal Demand. The TDWR provided benthal loads within their models specific to Spring Creek, Cypress Creek, Clear Creek, Houston Ship Channel. When not provided, benthal demand is assumed to be included in the background conditions.

Background Conditions

The segment analysis and alternative technical subplans are developed for critical stream conditions defined as the 2-year, 7-day low flow. This information was developed by the TDWR for classified segments. H-GAC supplied the critical flow data for

TABLE II-4

SEPTIC TANK FACTORS

Basin	BOD (lb./person	Fecal Coliform (MPN/person)
Spring Creek	0.001	1.46×10^6
Cypress Creek	0.009	1.25×10^7
Lake Houston	0.008	1.05×10^7
Clear Creek - Nontidal	0.005	8.66×10^6
Clear Creek - Tidal	—	----
Clear Lake	—	----
Armand Bayou	0.007	9.21×10^6
Dickinson Bayou - Nontidal	0.006	7.50×10^6
Dickinson Bayou - Tidal	0.006	7.50×10^6
Houston Ship Channel	—	----
San Jacinto River - Tidal	0.007	9.61×10^6
White Oak Bayou	0.007	9.00×10^6
Buffalo Bayou	0.009	1.20×10^6
Brays Bayou	—	----
Sims Bayou	—	----
Vince Bayou	—	----
Hunting Bayou	—	----
Greens/Halls Bayou	0.007	9.37×10^6
Carpenters Bayou	0.004	6.12×10^6

unclassified segments.

Headwater flows, major tributaries, and runoff contributions are presented in Table II-6.

It should be noted that the 2-year, 7-day low flow for the San Jacinto River is zero due to controlled discharge at the Lake Houston dam.

The background water quality of the stream segments is developed consistent with the TDWR wasteload allocation methodology. The following parameters were utilized throughout the planning area:

1) Critical temperature of 85°F

2) BOD of 1.0 mg/L

3) Dissolved oxygen (nontidal) 7.56 mg/1 (saturation)

4) Dissolved oxygen (tidal) 7.50 mg/1 (saturation)

Levels of Water Quality

Three levels for dry weather water quality criteria are being considered during the development of the segment analysis and the alternative technical subplans. These water quality criteria are defined as follows:

Level I. The water quality that will result from continuing future operations at the existing permitted level of treatment.

Level II. The water quality standards adopted in January 1977 by H-GAC through a combined effort of citizens workshops and advisory committees. These criteria are known as the 1977 standards.

Level III. The water quality standards adopted for implementation in 1983 which are capable of meeting the defined goal of "fishable/swimmable" streams.

Since the numerical values of water quality level I are a product of the segment analysis, they are not definable at this time. Therefore, they will be presented with the results of the segment analysis.

TABLE II-6

2-YEAR 7-DAY LOW FLOWS AT HEADWATERS

Spring Creek	0.897	cfs
Willow Creek	0.482	cfs
Panther Creek	0.536	cfs
Brushy Creek	0.863	cfs
Walnut Creek	1.495	cfs
Mill Creek	1.402	cfs
Dry Creek	0.304	cfs
Runoff and Inflows	2.516	cfs
Cypress Creek	0.19	cfs
Lake Houston	65.52	cfs
Clear Creek - Nontidal	0.22	cfs
Hickory Slough	0.01	cfs
Mud Gulley	0.01	cfs
Turkey Creek	0.01	cfs
Mary's Creek	0.01	cfs
Clear Creek - Tidal	18.20	cfs
Clear Lake	22.36	cfs
Armand Bayou	0.51	cfs
Dickinson Bayou - Nontidal	0.1	cfs
Dickinson Bayou - Tidal	0.1	cfs
Houston Ship Channel[1]		
San Jacinto River - Tidal	0	cfs
White Oak Bayou	0.93	cfs
Buffalo Bayou	2.00	cfs
Brays Bayou	0.82	cfs
Sims Bayou	1.93	cfs
Vince Bayou	0.52	cfs
Hunting Bayou	0.92	cfs
Greens Bayou	1.12	cfs
Halls Bayou	0.89	cfs
Carpenters Bayou	0.01	cfs

[1] Headwater flow equal to Buffalo Bayou flow at the Turning Basin.

The numerical criteria defined for water quality levels II and III are presented in Table II-7.

Stream Simulation Models

Several water quality stream simulation models are utilized to perform the segment analysis for steady state conditions. Inputs to the various models include both point and nonpoint wasteloads. An allowance is made for degradation of discharges into tributaries prior to entering the modeled portion of the stream segment. This degradation is calculated based on the Streeter-Phelps equation utilizing coefficients consistent with other models being applied within the area.

The following is a brief description of the simulation models utilized for the segment analysis and the development of alternative technical subplans in the 208 area. Complete documentation of the simulation models is available through H-GAC.

QUAL-II. The Stream Quality Model QUAL-II, provided by the TDWR, is utilized for simulating steady-state condition for the following stream segments; Spring Creek, Cypress Creek, and Clear Creek. QUAL-II simultaneously exerts the effects of carbonaceous BOD, nitrogenous BOD, and benthal demand upon the modeled stream. This model was calibrated but not verified by the TDWR specifically for each of the three creeks.

Houston Ship Channel Model. The O'Connor-Hydroscience Houston Ship Channel Model was developed by the TDWR specifically for that stream segment. The one dimensional mathematical model determines the effects of carbonaceous BOD (C BOD) and nitrogenous BOD (N BOD) separately. Therefore, to determine the combined effects of C BOD and N BOD, the resulting dissolved oxygen (D.O.) profiles are combined for each portion of the stream.

AUTO-SS. The San Jacinto River water quality simulation is performed with the AUTO-SS model, as calibrated but not verified by the TDWR. AUTO-SS is a longitudinal steady-state model designed specifically for water bodies where widths are small relative to their length and whose net circulation patterns are essentially unidirectional.

The quality solutions in AUTO-SS are based on mass balance equations at each junction. Constituents capable of being modeled are C BOD, N BOD, D.O., and conservative materials.

Lake Houston Modeling. Lake Houston water quality is simulated by a simplified mass balance approach. The calculation assumes a completely mixed system for the reservoir.

TABLE II-7

PROPOSED ALTERNATIVE WATER QUALITY STANDARDS

Stream	Alternatives*	Water Use Criteria				Numerical Criteria**	
		Non Contact Recreation	Contact Recreation	Fish/ Wildlife	Water Supply	Oxygen mg/1 (Not Less Than)	Fecal Coliform MPN/100 ml (Not More Than)
San Jacinto River - Tidal Portion	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
Lake Houston	A	Yes	Yes	Yes	Yes	5.0	200
	B	Yes	Yes	Yes	Yes	5.0	20
Houston Ship Channel - Lower	A	Yes	No	Yes	No	4.0	1,000
	B	Yes	Yes	Yes	No	5.0	200
Houston Ship Channel - Upper	A	No	No	No	No	2.0 3.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Houston Ship Channel - Turning Basin	A	No	No	No	No	1.5 3.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Spring Creek	A	Yes	No	Yes	Yes	5.0	2,000
	B	Yes	Yes	Yes	Yes	5.0	200
Cypress Creek	A	Yes	No	Yes	Yes	5.0	2,000
	B	Yes	Yes	Yes	Yes	5.0	200
Clear Creek - Tidal	A	Yes	No	Yes	No	4.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Clear Creek - Above Tidal	A	Yes	No	Yes	No	5.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Dickinson Bayou - Tidal	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
Dickinson Bayou - Above Tidal	A	Yes	No	Yes	No	5.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Clear Lake	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
Tabbs Bay	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
San Jacinto Bay	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
Black Duck Bay	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
Scott Bay	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200
Burnett Bay	A	Yes	Yes	Yes	No	4.0	200
	B	Yes	Yes	Yes	No	5.0	200

TABLE II-7

PROPOSED ALTERNATIVE WATER QUALITY STANDARDS

(continued)

Stream	Alternatives*	Water Use Criteria Non Contact Recreation	Contact Recreation	Fish/ Wildlife	Water Supply	Numerical Criteria** Oxygen mg/l (Not Less Than)	Fecal Coliform MPN/100 ml (Not More Than)
Vince Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Armand Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Buffalo Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Sims Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Greens/Halls Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Brays Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Hunting Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
White Oak Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200
Carpenters Bayou	A	Yes	No	No	No	2.0	2,000
	B	Yes	Yes	Yes	No	5.0	200

*A third alternative will be considered. This technology option will assume that current effluent limitations (1977) will remain, and the resultant stream quality will be determined.

**No stream standards will be set for suspended solids. Control strategies will be analyzed for various load reductions on streams where suspended solids have a significant impact on the stream.

Background data and physical characteristics were obtained from the TDWR's wasteload allocation report and from a report titled, "Report on Lake Houston, Harris County, Texas", March 1977 published by the Environmental Protection Agency as part of the National Eutrophication Survey Program. A summary of coefficients and inputs used in the mass balance calculation are contained in Appendix A.

SAC III. The remaining nontidal stream segments are modeled by the Stream Assimilative Capacity Model, SAC III, developed by Roy F. Weston, Inc. SAC III is a multi-purpose program for simulating dissolved oxygen levels in a stream resulting from a sequence of point source wasteloads. The Streeter-Phelps one dimensional steady-state differential equations are used to perform the water quality simulation with the given waste flow, wasteload characteristics, receiving stream characteristics, reaction rate constants, and temperature. The net oxygen deficit is calculated by determining the individual contributions of all upstream point source wasteloads.

SAC III is also capable of determining point source wasteload reduction requirements in order to maintain a specified dissolved oxygen content in the stream segment. The calculated reduction is based on the wasteload's proportional contribution to the overall deficit at the critical point in the stream.

A summary of required inputs and constants used in the application of SAC III are contained in Appendix A.

EPA Simplified Model. The remaining stream segments affected by tidal influences are modeled by EPA's Simplified Mathematical Modeling of Water Quality. This method of analyzing tidal segments is very similar to simplified modeling of nontidal streams, with the exception of the introduction of a dispersion coefficient to allow for the mixing effect of current reversals. A summary of the inputs to this analysis is presented in Appendix A. Assumptions for coefficient values are based upon information contained in the TDWR's waste load evaluation reports or typical data for each type of stream segment obtained from the documentation report on the "Simplified Mathematical Modeling of Water Quality", EPA, March 1971.

A discussion of model validity is contained in Appendix A.

Summary of Dry Weather Segment Analysis Methodology

The 1995 wasteloads are input to the water quality simulation models according to current effluent limitations in order to determine problem areas within the segment. If all water quality standards are met, the initial dry weather segment analysis is complete. When standards are violated, the degree of wasteload reduction necessary to achieve water quality standards is determined. Wasteload reductions are based upon point and nonpoint source control strategies (as defined in the Point Source Analysis and the Nonpoint Source Analysis) and the effluent limitation sets defined by the TDWR.

Since an infinite number of possible subplans exist for a given level of load reduction, the segment analysis is performed according to the following concepts:

- Nonregionalization of treatment plants
- Semi-regionalization of treatment plants
- Regionalization of treatment plants.

Many themes of treatment for each concept are evaluated on a preliminary basis, with only the most viable ones retained for a detailed analysis.

The result of the segment analysis is the definition of allowable loading sets for each level of water quality. The control strategy for accomplishing these wasteload reductions is developed in the alternative technical subplans.

Technical Subplan Methodology - Dry Weather

General

Alternative technical subplans are developed for stream segments based on the results of the segment analysis. The segment analysis presents the generalized types of wasteload reduction and water quality management actions which are necessary to meet stated water quality goals.

Specific strategies for achieving the necessary wasteload reductions are developed in the Point Source Analysis and the Nonpoint Source Analysis reports. These strategies are utilized as the basis for control themes in the development of the alternative technical subplans. Control themes are applicable to both the existing sewage treatment systems and the newly proposed sewage treatment systems. The control themes are first applied to specific problem areas identified in the segment analysis. The themes are also applied to the wasteloads resulting from various management actions such as regionalization of municipal treatment systems.

Existing Wastewater Treatment Facilities

An inventory of existing waste treatment facilities is contained in the Point Source Analysis report. Data in this inventory include the following items for domestic treatment plants: Name of Permitee, Plant Name, Waste Control Order, Address, Telephone Contact, Segment, Subbasin, Stream Index No., Location (Latitude/Longitude), Census Tract, Discharge Route, Plant Capacity, Population Served, Construction Date, Treatment Process, Planned Improvements, Compliance Schedule, Enforcement Order, Permit Limitations, Self-Reporting Data.

Not all data are available for every facility. The most critical item of information which is unavailable for a significant number of facilities is the existing treatment process. In such cases it is assumed that the process is capable of producing effluent level 2. Another assumption is required due to the fact that the information does not differentiate between typical activated sludge and modified activated sludge (enhanced solid separation). Again, the waste control order is utilized as the basis for assumptions. If the order stipulates an effluent suspended solids requirement of 20 mg/1, typical activated sludge is assumed to be in place, whereas if the order stipulates an effluent suspended solids requirement of 15 mg/1, modified activated sludge is assumed to be in place.

Information items in the inventory for industrial treatment plants include the same information as the domestic inventory with the following exceptions: additional data - SIC numbers, wastewater type; deletions - capacity, population served, construction data, planned improvements. In all cases it is assumed that industrial treatment facilities have or will have the processes required to allow the industrial point source projections to be met.

In order to update the inventory to include improved or new facilities which are presently being planned, designed, or constructed, the inventory base is expanded through the use of completed or ongoing Facility Plans. The list of Facility Plans included in the data base is as follows:

City of Baytown - West District
City of Brookside Village
City of Friendswood and GCWDA Blackhawk Regional STP
Galveston County WCID No. 12
Harris County FWSD No. 6
Harris County MUD No. 50

City of La Porte
City of Lomax
Montgomery County MUD No. 6
Montgomery County WCID No. 1
City of Pasadena
City of Pearland
San Leon Municipal Utility District
Spenwick Place MUD
Harris County WCID No. 21
City of Houston -
  Houston Northside
  Houston Northeast and Northwest
  Houston Southwest
  Houston Southeast
  Almeda-Sims Regional Treatment Plant
  Almeda-Sims Regional Sludge Treatment Plant
  Almeda-Knight-Cambridge Trunk Sewer
  District No. 47 Trunk Sewer
  Easthaven Sewage Treatment Plant
  Northwest Sewage Treatment Plant
City of Jersey Village

The technical subplan process considers these planned facilities to be in place for the purposes of determining required new plant capacity.

Development of Concepts and Themes

The segment analysis determines critical areas of the stream, types of wasteloads to be controlled and approximate levels of controls. The technical subplan utilizes the segment analysis information and develops specific groups of strategies to obtain the stated water quality objectives.

In order to differentiate large hydraulic elements into more readily analyzed sizes, the major areas are further subdivided. For example, the Spring Creek/Cypress Creek/Lake Houston area is divided into three hydrologic units: Spring Creek, Cypress Creek, and Lake Houston. These again are subdivided into geographical planning areas. The geographical planning areas are predicated on stream problem areas, logical grouping of existing service areas, land use patterns, existing facilities, and facility plans.

It is emphasized that the newly defined geographic planning areas are not meant to imply that the area is or will be a single service area. These areas are developed only to further subdivide the drainage basin and are presented only for a frame of reference. Several plants may be proposed for a given geographic area. However, for simplicity it is assumed that all wasteload reduction and control themes in a given geographical planning area are applied in a similar fashion.

Populations and wasteloads are developed for each geographic area in the following manner:

1) The total projected population in each geographical planning area is determined by distributing the census tract information contained in the July 1976 Population and Land Use Report for the Greater Houston Area, to their respective geographical planning areas.

2) Population and wasteloads projected for existing municipal service areas are obtained from the Point Source Analysis Report. This value is subtracted from the total projected population. The difference is the projected population outside of existing service areas.

3) New additional service areas within the geographical planning area are defined based on the single family and multi-family land use. The new service areas are assumed to generate wastewater at the rate of 100 gallons per capita per day.

4) Industrial wasteloads are obtained from the Point Source Analysis and are disaggregated along the stream according to the location of existing industrial activity.

The result is a list of geographical planning areas, population projections for each geographical planning area and the total wasteload generated in each geographical planning area.

Once the geographical planning areas are defined, wasteload control through management techniques such as regionalization of treatment plants can be applied. Three regionalization concepts are considered during the development of alternative technical subplans and are defined as follows:

Concept A. Concept A assumes that sewage treatment systems will develop to serve special population clusters such as new subdivisions, with little or no consideration to the treatment needs or excess capacity in neighboring treatment systems. Concept A is the nonregional concept of sewage treatment.

Concept B. Concept B assumes that certain geographical planning areas are grouped together and larger sewage treatment systems are developed to serve this broader population base. The result is fewer treatment plants, less unused capacity and greater transportation costs. Concept B is the semi-regional concept of sewage treatment.

Concept C. Concept C is a fully regional concept. It assumes a grouping of the semi-regional facilities defined for Concept B. This results in larger and fewer treatment systems than the semi-regional concept.

While the concepts address the alternate geographic extent of managing wastewater, themes are developed to address the alternative methods by which wastewater may be managed. The initial element in defining themes is the segment analysis which defines the major problem areas within the stream segment. Then wastewater management practices which are capable of solving the water quality problems are defined and screened. Through an initial screening process, the least suitable practices are deleted and the most promising retained for further investigation. In order to reduce the number of alternative combinations to be evaluated, a given water quality management technique is applied throughout a geographical planning area. This is referred to as a thematic approach.

Themes are applied to various concepts in the development of alternative technical subplans. In order to reduce the total number of alternatives to be evaluated, each theme is not applied to every concept. For example, the theme for achieving the desired water quality in a specific drainage basin may be to add nitrification to the sewage treatment process. The control theme of adding nitrification is applicable to the nonregional concept as well as the semi-regional and fully regional concepts. However, the theme may be evaluated for only the semi-regional concept (Concept B) at this time. If at a later time, the control theme becomes the selected alternative, the theme can be evaluated with the remaining two concepts.

The above approach limits the number of combinations to be presented and evaluated but increases the flexibility and number of alternatives that may be explored. Through the review process, favored themes and concepts can be identified independently and ultimately combined to produce a preferred subplan. The selected subplan can be a combination of any of the themes/concepts presented. The selected subplan can also apply one theme/concept in one portion of the basin while applying another theme/concept in another portion of the basin.

The simulated water quality produced by each theme/concept is identified. If the resulting water quality meets or exceeds the defined criteria, the basic theme is then modified to approach an optimal control theme. For example, a basic theme may involve increasing the level of sewage treatment to include tertiary treatment. However, the results of the water quality simulation may indicate that certain plants in the geographical planning area can discharge at the secondary treatment level without creating adverse effects on the desired water quality. Therefore, the alternative technical subplan based on the original theme will also identify those plants that may not require full implementation of the control theme.

In some instances, primarily nonpoint source wasteloads, strategies to control certain categories of wasteloads are not defined due to the developing state of the art. In such instances, levels of control are presented without defining actual methods for achieving the specified wasteload reduction.

Applicable Control Themes for Wastewater Treatment

For the case of treating point source discharges, the effluent criteria considered are selected to be consistent with Federal or State defined effluent criteria. In the case of industrial point sources, BAT and BPCT are assumed (consistent with industrial wasteload projections).

In the case of municipal point sources, upgraded effluent criteria developed for treatment strategies are in conformance with TDWR's "Policy for Effluent Standards for Domestic Wastewater Treatment Plants". These criteria , as well as the corresponding treatment processes, as defined by TDWR, are presented in Table II-2. The only deviation from these criteria is that a new group of effluent sets has been defined to include all previous sets plus the additional process of effluent aeration.

Numerous strategies or combinations of strategies can be utilized to reach a given effluent set. In order to achieve consistency, and to allow the subplan development to address area-wide concepts rather than optimizing specific processes, standard treatment schemes are utilized for upgrading existing plants, expanding existing plants, or constructing new plants.

Table II-9 presents the unit processes required to achieve the defined effluent sets. The costs associated with the existing and upgraded sewage treatment strategies are based in part on these defined unit processes.

TABLE II-9

UNIT PROCESSES ASSOCIATED WITH EFFLUENT SETS

	Processes						
Effluent Set	Basic[1] Process	Excess Clarifier Capacity	Polymer Addition Prior to Final Clarification	Effluent Filtration	Biological Nitrification	Effluent[2] Aeration	Chemical Addition/ Phosphorus Removal
1	X						
2	X	X					
3	X	X	X				
4	X	X	X	X			
N					X		
P							X
A						X	

1 Up to 7.5 MGD - Preliminary Treatment, conventional activated sludge, chlorination, aerobic digestion, sludge drying beds. Greater than 7.5 MGD - Preliminary Treatment, conventional activated sludge, chlorination, aerobic digestion, vacuum filters.
2 Up to 1.0 MGD - Cascade aeration. Greater than 1.0 MGD - Diffused aeration.

Technical Subplan Evaluation - Dry Weather

Cost Evaluation

A major consideration in the selection of an areawide management plan is the estimated cost for implementation of the plan. In order to assess the financial impact of the various alternative technical subplans, cost estimates are presented for all of the themes/concepts evaluated.

Capital costs and operation and maintenance costs for sewage treatment facilities are estimated based on data provided in the Point Source Analysis report. Capital costs and operation and maintenance costs for sewage collection facilities are based on information developed by Roy F. Weston, Inc. for the Greater Houston Area 208 Program.

Major assumptions made during the development of the cost estimates are as follows:

1) If additional treatment capacity is provided by expanding an existing facility, the cost of the required expansion is taken as equivalent to the cost of a new facility of capacity equal to the expansion requirement.

2) Raw sludge production for biological plants is 0.5 ton per MGD whereas digested sludge production is 0.25 ton per MGD.

3) If the ratio of expanded plant size to new plant size is more than 5:1, a totally new plant is required.

4) Pumping from an abandoned plant does not require a new lift station.

5) Pipe length for conveyance is equal to 115 percent of the straight line length.

6) If sewage is to be transported less than one mile, it is assumed that it can be conveyed through intermediate collector lines.

7) Pumping utilizes 100 feet of head and can be accomplished for a maximum of five miles without intervening pump stations.

8) Land application requirements are 62 acres/MGD.

The total capital expense and the total annual operational and maintenance expense are combined to develop a total present worth evaluation. The most accurate present worth analysis feasible would take into account the actual projected time phasing of plants, thus having an exact expenditure cycle and a time dependent increase in total operation and maintenance costs. However, this is neither feasible nor desirable because in considering alternative technical subplans, it is preferable to present a larger number of themes with less detail rather than present a fewer number of themes with greater detail. The detailed phasing is developed for the preferred subplan.

In order to determine the present worth without a detailed phasing analysis, certain assumptions are made. These are as follows:

1) For capital costs it is assumed that:

    a) Any facility upgrading takes place in 1983.

    b) New facilities costs for the nonregional concept are assumed to take place in equal expenditures each year between 1977 and 1995.

    c) Semi-regional and regional facilities are assumed to be constructed in 1983.

2) For operation and maintenance costs of the nonregional concept it is assumed that:

    a) Existing facility operation and maintenance costs occur at a uniform rate for the 1977-1995 period.

    b) Upgrade portions of existing facility operation and maintenance costs occur at a uniform rate for the 1983-1995 period.

    c) New facility operation and maintenance costs increase uniformly from zero in 1977 to full value in 1995. For simplicity, average operation and maintenance for three periods, 1977-1983, 1984-1990, and 1991-1995 are calculated.

3) For operation and maintenance costs of the semi-regional and regional concepts it is assumed that:

    a) Existing facility operation and maintenance costs occur at a uniform rate between 1977 and 1983.

b) New facility operation and maintenance costs occur at a uniform rate between 1983 and 1995.

It should be noted that the present worth analysis is based on an interest rate of 6.125 percent and on present day dollars. Inflation is not taken into account. The exclusion of inflationary effects causes annually recurring operational and maintenance costs to have a lower present worth value than if inflation was not excluded, while having lesser effects on the capital investments. The net result is that the present worth analysis is somewhat biased in favor of annual operation and maintenance expenses.

While it is the opinion of this program's Technical Advisory Committee that the present worth analysis should not exclude the effect of inflationary trends, such exclusion has been made to conform with EPA guidelines.

Each theme/concept evaluated includes an estimate of present worth cost and water quality level achieved. The following assumptions should be considered when analyzing the present worth cost estimates:

1) Cost figures presented do not include any existing bonded (or other) indebtedness.

2) Cost figures presented for themes/concepts achieving water quality level I are estimates of cost to provide the existing permitted level of sewage treatment control to the present and future population in the drainage basin.

3) Cost estimates presented for achieving water quality levels II and III through the implementation of themes/concepts are indicative of the costs to provide sewage treatment to the present and future population in the drainage basin while at the same time, achieving improved water quality.

Relative costs for various levels of treatment and degrees of regionalization are presented in Appendix C on a dollar per thousand gallons per day per year basis. Appendix D contains an example of the data development and present worth evaluation performed for the alternative technical subplans.

Segment Analysis Methodology - Wet Weather

General

The wet weather segment analysis is performed in order to assess the effect of both dry weather and storm water wasteloads on water quality conditions. Several of the stream segments within the 208 planning area are analyzed with the aid of storm water simulation models.

The segment analysis identifies any problem areas within a stream segment and determines the allowable loadings in order to maintain water quality. The results of the segment analysis are used as the basis for any alternative technical subplans which may be developed.

The inputs and defined critical conditions for the wet weather segment analysis are presented within this section.

Modeled Segments

Spring Creek, Cypress Creek, Clear Creek nontidal, the Houston Ship Channel, and the San Jacinto River are analyzed through the use of the nonsteady state storm water simulation model WRECEV. WRECEV is a modified version of the Receiving Water Module (subroutine RECEIV) of the Storm Water Management Model (SWMM).

The prototype system is represented numerically as a set of channels which connect at junctions. Utilizing this representation, the RECEIV Model first solves the continuity and energy equations to simulate the movement of water within the system (Hydrodynamic Model), and then solves the advection-diffusion-mass transport equation to determine the temporal and spatial distributions of conservative and nonconservative constituents contained within the waters of the system. WRECEV simulates 5 days of steady-state conditions prior to the storm. The storm is applied during the first hour of the sixth day.

The parameters evaluated in the planning area streams modeled by WRECEV are dissolved oxygen, biochemical oxygen demand, and total coliform. Fecal coliform were assumed to be ten percent of total coliform as provided by the H-GAC and TDWR based upon available data.

WRECEV is calibrated by the TDWR. Complete documentation of the storm water simulation model is available through H-GAC.

Point Source Wasteloads. Industrial and municipal point source wasteloads are utilized as steady-state inputs to the non-steady-state water quality simulation model, WRECEV. Initially, two sets of point source wasteloads are input to the model in order to compare their effects on the resulting water quality. The first wet weather simulation run utilizes point source wasteloads based upon future wastewater flows at presently existing permitted discharge levels as allocated in the Wasteload Evaluation Report for the segment.

A second simulation run is performed with future point source wasteloads based on one of the alternative technical subplans developed for dry weather conditions. The results of the two initial simulation runs are compared to determine the effects of dry weather subplans on the water quality resulting during storm conditions.

Nonpoint Source Wasteloads. Steady-state and stormwater related nonpoint source wasteloads are major inputs to the nonsteady-state water quality simulation model. Stormwater related nonpoint source wasteloads utilized in the segment analysis are developed for the 2-year, 1-hour design storm of 2.35 inches. Information concerning the nonpoint source wasteloads is contained in the Nonpoint Source Analysis.

Background Conditions. Background flows utilized in the non-steady-state model are based upon summer average daily conditions derived from five years of data recorded at USGS gauging stations for July, August and September. The summer average daily flows as developed by the TDWR for the wet weather analysis are listed in Table II-8.

Background water quality is considered as follows:

Temperature	27°C
BOD	1.0 mg/l
Dissolved Oxygen (saturation)	8.0 mg/l

Unmodeled Segments

The evaluation of the unmodeled segements involves a comparison to the resultant water quality of a modeled segment having similar land uses and growth patterns.

TABLE II-8

SUMMER AVERAGE DAILY FLOWS

Spring Creek

Junction		Flow
1	LP 10 - Spring Creek Headwaters/ Brushy Creek	24.15 cfs
2	LP 20 - Walnut Creek	22.47 cfs
3	LP 30 - Mill Creek	21.53 cfs
5	LP 40 - Dry Creek	7.88 cfs
8	LP 50 - Willow Creek	17.01 cfs
9	LP 60 - Panther Branch	11.55 cfs
14	LP 70 - Incremental Runoff	8.09 cfs
14	Cypress Creek	149.00 cfs

Cypress Creek

Junction		Flow
1	LP 10 - Mound Creek/Snake Creek	21.60 cfs
2	LP 15 - Live Oak Creek	9.00 cfs
3	LP 20 - Sharp Road	5.04 cfs
4	LP 25 - Rock Hollow	9.72 cfs
5	LP 30	8.88 cfs
7	LP 35 - Dry Creek	12.48 cfs
9	LP 40 - Little Cypress Creek	23.04 cfs
10	LP 45 - Faulkey Gulley	7.80 cfs
15	LP 50 - Spring Gulley	12.12 cfs
17	LP 55 - HC Flood Ditch	5.04 cfs
19	LP 60 - I-45 Incremental Runoff	5.28 cfs
23	LP 65	11.04 cfs
24	LP 70 - Confluence with Spring Creek Incremental Runoff	2.28 cfs

Clear Creek

Junction		Flow
1	Clear Creek Headwaters	5.42 cfs
3		7.30 cfs
10	Mary's Creek	39.79 cfs
11	Cowart Creek	36.14 cfs

TABLE II-8 (CONTINUED)

SUMMER AVERAGE DAILY FLOWS

Houston Ship Channel

Junction		Flow
1	Buffalo Bayou/White Oak Bayou	502.0 cfs
23	Brays Bayou	170.0 cfs
24	Sims Bayou	84.0 cfs
25	Vince Bayou	18.0 cfs
26	Hunting Bayou	22.0 cfs
27	Greens/Halls	78.0 cfs

San Jacinto River

Summer Average Daily Background Flows = 0

Levels of Water Quality

At present, no water quality criteria exist specifically for wet weather conditions. Therefore, an initial evaluation of stream quality is made based upon the existing and proposed dry weather standards. Level I, as discussed in the dry weather segment analysis, is the continuation of existing technology, Levels II and III are based upon existing and proposed numerical standards for dissolved oxygen and fecal coliform as previously listed.

If wet weather stream quality meets or exceeds the dry weather standards, the analysis is complete and no control themes are necessary. If these standards are not met, an analysis is made to determine the impact on the stream quality and the effect on its water uses. One of the objectives of this program is to determine if separate water quality standards should be developed for wet weather conditions.

Summary of Wet Weather Segment Analysis Methodology

The 1995 steady-state point and nonpoint source wasteloads along with the stormwater runoff related nonpoint wasteloads are input to the wet weather water quality simulation model in order to determine problem areas within the segment. The results are initially evaluated according to dry weather standards. If these standards are met, the segment analysis is complete. If dry weather standards are not met, an evaluation is made to determine the impact of the wasteloads on the stream and its water uses.

Based on the impacts to the stream segment, allowable loadings are determined and wasteload reductions identified. Technical subplans are then developed to accomplish the required wasteload reductions.

Technical Subplan Methodology and Evaluation - Wet Weather

General

Alternative technical subplans are developed for stream segments based on the results of the segment analysis. The segment analysis presents generalized reductions in runoff loads necessary to maintain a water quality that preserves the water uses of the segment.

Specific strategies for achieving wet weather wasteload reductions are presented in the Nonpoint Source Analysis Report.

These strategies are utilized as the basis for control themes in the development of alternative technical subplans. General areas within the drainage basin which contribute the heaviest runoff loads are identified and a method for applying control themes is devised.

Development of Themes

The general areas within a drainage basin contributing the heaviest runoff loads are identified by consulting several sources. The Nonpoint Source Analysis Report categories the total nonpoint source loads to the segment from urban land uses, septic tanks, agriculture, and construction activities, thus indicating the types of activities producing the heaviest loads. The segment analysis identifies critical points on the stream where the wasteloads cause water quality problems. The projected land use within the area draining to the critical point on the stream is then examined to determine the location of the type of activity identified as the major contributor of runoff loads.

Once general areas have been identified as sources of major stormwater runoff loads, controls are investigated in order to provide the desired load reduction. Control strategies are selected based upon the ranking of strategies presented in the Nonpoint Source Analysis Report. The evaluation categories of ranking include effectiveness, feasibility, applicability, impacts on the ecosystem, socio-political impact, economic impact, land use, capital cost, and operation and maintenance costs.

Unfortunately, the technical basis does not exist at this time to precisely quantify the effectiveness of many of the control strategies. Test areas, where several of the higher rated strategies are implemented and their effectiveness monitored, are suggested. The control strategies to be monitored should also be chosen for their minimum committment of resources since their ability to provide desired load reductions is not known. Test areas should be selected based upon their typicality, minimum size, and minimum economic and social disruption.

Once the effectiveness of various controls techniques is documented in the test areas, those controls providing the desired reductions should be implemented as a full scale program in the entire area.

Evaluation of Themes

The evaluation of control strategies is performed in the Nonpoint Source Analysis Report by the ranking procedure previously discussed. The control strategies to be implemented are selected based upon their ranking among the various evaluation criteria.

The cost evaluation performed is a comparison of relative costs between strategies. No specific cost figures are provided since many of the controls on urban runoff are heavily dependent upon the placement of land. Detailed information on availability of land within urban areas, specific physical characteristics of the land, and cost of the land have not been provided as inputs to this program.

CHAPTER III - SPRING CREEK/CYPRESS CREEK/LAKE HOUSTON

CHAPTER III - SPRING CREEK/CYPRESS CREEK/LAKE HOUSTON

Introduction

The Spring Creek/Cypress Creek/Lake Houston technical subplanning area is located in the northern third of the 208 planning area (see Exhibit III-1). The major waterways within this area include Spring and Cypress Creeks whose basins are absorbing much of Houston's rapid growth and Lake Houston which serves the City of Houston as a major water supply. For ease of discussion, development of the alternative technical subplans has been addressed by each basin.

Spring Creek

Description of Area

Spring Creek is located approximately twenty-five to thirty miles north of downtown Houston. It flows in a west to east direction forming the boundary between Harris and Montgomery counties. The Creek's headwaters are found in sparsely populated farm and ranch land in northeast Waller County. It flows for approximately 68 miles before reaching the upper arm of Lake Houston.

The Creek has a drainage area of approximately 438 square miles and includes the following tributaries: Willow Creek, Panther Branch, Mill Creek, Walnut Creek, Brushy Creek, and Cypress Creek. Land use within the Spring Creek drainage area has historically been rural and agricultural. However, Houston's suburbs are rapidly advancing towards the Spring Creek watershed and the area is becoming more urbanized. Significant urban growth is projected during the planning period throughout the basin, with major growth occurring in the Woodlands area, near the City of Magnolia, and along the Creek's banks. The total basin population that will be served by municipal treatment plants is projected to by 71,500 by 1995.

Results of Dry Weather Segment Analysis

The QUAL-II Water Quality Simulation Model calibrated (but not verified) by the TDWR is utilized for the dry weather segment analysis. This model, as discussed in the methodolody section, includes Spring Creek and two of its tributaries, Willow Creek and Panther Branch.

Many domestic wastewater treatment plants discharge into the basin, most of which are located in the lower half of the Creek. No industrial discharges are projected during the planning period.

The basin is divided into 16 geographical planning areas by the methods discussed previously. The location of each area and the manner in which they are combined for the concepts of semi-regionalization and regionalization are indicated on Exhibits III-2 through III-4.

The water quality levels addressed for this segment are presented in Table III-1.

TABLE III-1

WATER QUALITY LEVELS
SPRING CREEK

Level	D.O. (mg/l)	Fecal Coliforms MPN/100 ml
I	As available from existing effluent set	As available from existing effluent set
II	5.0	< 2000
III	5.0	< 200

Projected water quality for Spring Creek was simulated with steady-state modeling techniques based on the 1995 future wasteloads and the existing level of wastewater treatment. Three regionalization concepts were analyzed based on the conceptualized geographical planning areas developed for the basin. Additionally, a "baseline" simulation was performed to determine the effects of channel conditions, stream hydraulics, and background benthal loads (see Appendix B, Figure III-1).

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration greater than 4.5 mg/l and that only in the upper reaches of the Creek near the first major point source discharger, does the D.O. level drop below 5.0 mg/l. Projected levels of fecal coliforms remain below 200 MPN/100 ml.

Additional conclusion developed in the segment analysis are:

(1) For dry weather conditions, nonpoint source wasteloads are not significant

(2) Other pollutants such as nutrients or conservative minerals do not present any problems for Spring Creek

(3) Nutrients discharged into Spring Creek are a major source of nutrients in Lake Houston. However, based on the Lake Houston segment analysis, control of nutrients into Spring Creek is not recommended at this time.

(4) The simulated water quality in Spring Creek will produce no detrimental effects to Lake Houston.

(5) The existing background benthal loading is not a significant problem in Spring Creek.

Analysis of Themes

The water quality projections, based on simulation modeling techniques, for Spring Creek, meet or exceed the fishable/swimmable criteria of Water Quality Level III, except for a five mile section of the stream where the projected dissolved oxygen concentration falls below 5.0 mg/l to 4.8 mg/l. This oxygen deficit based on the projected 1995 wasteloads is considered within the accuracy of the modeling process. Therefore, Spring Creek meets the desired water quality and requires no further analysis. The only theme to be evaluated is the theme calling for a continuation of the existing level of technology, as described below.

Theme	Description
1	Continue operation of existing plants at effluent set 2. Construct any future facilities for operation at effluent set 2.

Discussion of Themes Evaluated

By definition, continuation of the existing level of technology produces Water Quality Level I in the stream segment. However, in this case, the resulting water quality meets or exceeds the water quality criteria specified by Levels II and III. The costs associated with this theme are indicative of the costs to provide sewage treatment to the existing and future projected population in the basin.

Table III-2 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE III-2

COMPARISON OF THEMES/CONCEPTS
SPRING CREEK

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional (A)	III	32	$21,700,000
1	Semi-regional (B)	III	4	17,400,000
1	Regional (C)	III	2	16,800,000

The stream segment profiles depicting dissolved oxygen concentrations for each of the themes/concepts described are presented in Appendix B, Figures III-2 through III-4.

Results of Wet Weather Segment Analysis

The WRECEV Water Quality Simulation Model is utilized for the wet weather segment analysis, as discussed in Chapter II. The simulation is applied over a twenty day period with the storm occurring in the first hour of the sixth day. Outputs are recorded for various time intervals at fifteen junctions in Spring Creek.

Currently, no standards exist specifically for wet weather situations. Therefore, the initial evaluation of resultant water quality is based upon dry weather standards.

Two simulations are performed with variations made in the point source wasteloads. The inital run is made with future point source wasteloads based upon presently permitted values as allocated in the Wasteload Evaluation Report. A second run is made with future point sources based upon one of the dry weather alternative technical subplans to verify that the initial simulation is representative of the results obtained with a technical subplan.

Figure III-5 presents the steady-state water quality conditions immediately before the storm. Figures III-6 through III-17 show the stream's response to the storm every two hours during the day of the storm's occurrence. Dissolved oxygen never drops below 6.0 mg/l. Data for the remaining days after the storm indicate that dissolved oxygen levels continuously increase throughout the period of simulation until reaching the steady state conditions of 7.5 to 8.0 mg/l. Thus, based upon this data, wet weather conditions are well above the dry weather standard for Spring Creek of 5.0 mg/l.

Fecal coliform concentrations are also indicated on Figures III-5 through III-17. The graphs show peaks in concentrations immediately after the storm that level out to approximately 1,000 MPN/100 ml by the end of the day of the storm. Junction 14, the confluence with Cypress Creek, and Junction 15 immediately downstream are the exceptions to this observation, with fecal coliform levels of 3,500 MPN/100 ml at the end of the day of the storm.

To determine if the simulated wet weather conditions meet dry weather standards for fecal coliform, the definition of the standards is first examined. The 1983 fishable, swimmable standards as directed by the TWQB for Spring Creek state that both of the following two cases must be met:

1) The geometric mean of fecal coliform concentrations recorded over 30 days must not exceed 200 MPN/100 ml.

2) Ten percent of the recorded samples must not exceed 400 MPN/100 ml.

Two critical locations are examined for Spring Creek during wet weather. The junction exhibiting the peak fecal coliform concentration is Junction 14. Figure III-18 shows the change in levels of fecal coliform at this junction throughout the time period simulated by the model. An additional ten days of data to complete the thirty day period was obtained by extrapolating between the concentration on the last modeled day and the steady-state conditions assumed to be reached by the thirtieth day. The geometric mean of these points is less than 100 and, therefore, well within the first condition of the standards.

The second condition of the standards is also complied with at this junction since concentrations remain above 400 MPN/100 ml for three days, or exactly ten percent of the time.

Another critical location is examined on Spring Creek at the junction exhibiting the longest lingering fecal coliform concentration. Junction 1, as shown in Figure III-19, does not have a peak concentration as high as Junction 14. However, fecal coliform concentrations do not drop down as rapidly at Junction 1. Determining the geometric mean of fecal coliform concentrations in the same manner as discussed previously indicates that average concentrations over thirty days remain well below 100 MPN/100 ml and within the standard.

The concentrations remain above 400 MPN/100 ml, however, for almost four days or thirteen percent of the period. This slightly exceeds the percent allowed under dry weather standards. Three other junctions, Junctions 2, 3, and 4, also remain above 400 MPN/100 ml for three and one-half to four days.

Based upon the inputs to the water quality simulation model for the design storm, wet weather conditions on Spring Creek are well within dry weather standards for dissolved oxygen. The condition of the fecal coliform standards that the geometric mean of the concentrations over a thirty day period remain less than 200 MPN/100 ml is consistently met. However, the condition of an allowable ten percent of the points in excess of 400 MPN/100 ml is violated at several junctions, indicating that lingering high fecal coliform concentrations may create potential problem areas during wet weather conditions in the upper reaches of the stream.

An additional analysis is performed to compare the total loadings of suspended solids from point sources and nonpoint sources. The Nonpoint Source Report identifies the total loadings of suspended solids to each basin per year. These total nonpoint source loadings for 1995 are compared to the total point source loadings from the recommended Alternative Technical Subplan for dry weather conditions. This information indicates that nonpoint sources contribute 70,000 tons/year while point sources contribute only 200 tons/year. A large portion of this load enters through stormwater runoff, resulting in very high concentrations during wet weather conditions. These high concentrations may damage the aesthetic appeal of the Creek and contribute to benthal demands. At this time, the information is not available to indicate the amount of harm caused by suspended solids. However, should suspended solids be found to create serious problems in Spring Creek, controls on nonpoint sources should be considered.

Discussion

The simulated water quality in Spring Creek is projected to meet fishable/swimmable standards during critical dry weather flows based on receiving wastewater discharges at Effluent Set 2. The water quality simulation is based on a nonverified model. The exception to the meeting of fishable/swimmable standards is in the upper reach of the Creek. The stretch below the initial discharge will exhibit a dissolved oxygen concentration of slightly less than 5.0 mg/l.

The validity of the stream D.O. projections is highly dependent on effluent ammonia levels (see Chapter VII). TDWR has generally estimated that Effluent Set 2 will produce ammonia-nitrogen concentrations of 8 mg/l or less. The actual performance of Effluent Set 2 plants will significantly affect the reliability of technical subplans utilizing Effluent Set 2.

The ratio of treated sewage flows to total flow in Spring Creek approaches unity. Plant effluents in this area at this time have residual chlorine far in excess of TDWR requirements, especially during early morning hours when sewage flow is low and chlorine feed rates are high. Thus, high residual chlorine concentrations have been reported in the Creek. Consideration should be given to placing a maximum level on chlorine residual in effluent.

Cost data for Spring Creek indicate that there is some incentive to regionalization in that area. However, these savings are not considerable and, considering the undetermined nature of population projections in that area, do not warrant moving directly to a capital intensive, regional approach. The feasibility of regionalization should be regularly re-evaluated as new land use patterns develop.

The simulated wet weather water quality is projected through use of an uncalibrated model, to meet or exceed fishable/swimmable standards during the design storm. Slight variances from the fecal coliform limitations are projected, but these are not significant.

The high water quality projected during wet weather in Spring Creek indicates that no definitive action need be taken for control of wet weather pollutants except to encourage the use of Best Management Techniques. However, the validity of the projection methods should be verified by wet weather water quality monitoring. Emphasis should be placed on:

- Dissolved oxygen concentrations.
- Rating of total coliform to fecal coliform.
- Evidence of lingering high coliform counts in the upper portion of the stream.

Conclusions and Recommendations

1) Continue to control point sources by wastewater treatment plants discharging at Effluent Set 2.

2) Consider placing a maximum ammonia-nitrogen limitation on wastewater discharges.

3) Consider placing a maximum chlorine concentration on wastewater discharges.

4) Continue utilizing nonregional treatment but be alert to potential cost savings inherent in regionalization.

5) Develop data on the action of nitrogenous oxygen demanding material as it relates to water quality.

6) Monitor wet weather water quality. Particular emphasis should be placed on dissolved oxygen and coliforms.

7) Encourage Best Management Practices, but implement no additional wet weather controls pending verification of wet weather water quality.

Cypress Creek

Description of Area

Cypress Creek is located fifteen to twenty miles north of Houston. It originates in eastern Waller County a few miles south of the City of Waller and flows in an eastward direction 58 miles to its confluence with Spring Creek, some 6 miles upstream of Lake Houston. The Creek has a drainage area of approximately 322 square miles including the major tributaries of Little Cypress Creek, which drains about 53 square miles, and Mound and Snake Creeks which together drain about 53 square miles.

Land use within the majority of the Cypress Creek basin has historically been rural. The upper half of the area is sparsely settled and consists largely of prairie land used for rice production and pasture. The lower half of the basin is in the midst of a rapidly growing surburan-residential development. This development is a result of the continuing expansion of the Houston metropolitan area and the desirability of the Creek's heavily wooded areas for residential sites.

This growth is projected to continue in a similar manner throughout the planning period. The basin's total population. that will be served by municipal treatment plants, is estimated to be 118,000 by 1995.

Results of Dry Weather Segment Analysis

The QUAL-II Water Quality Simulation model calibrated (but not verified) by the TDWR is utilized for the dry weather segment analysis. This model, as discussed in the methodology section, includes the entire length of Cypress Creek. As a result of the rapid growth experienced in the area, numerous domestic sewage treatment plants have been built along Cypress Creek and its tributaries. Thirty-one permitted dischargers exist along the Creek, with twenty-nine of these lying in the twenty-mile reach between U.S. 290 on the west and Aldine-Westfield Road on the east. No major industrial dischargers are projected during the planning period.

The basin is divided into 18 geographical planning areas by the methods previously discussed. The location of each area and the manner in which they are combined for the concepts of semi-regionalization and regionalization are indicated on Exhibits III-2 through III-4.

The water quality levels addressed for this segment are presented in Table III-3.

TABLE III-3

WATER QUALITY LEVELS
CYPRESS CREEK

Level	D.O. (mg/1)	Fecal Coliforms MPN/100 ml
I	As available from existing effluent sets	As available from existing effluent sets
II	5.0	<2000
III	5.0	<200

Projected water quality for Cypress Creek was simulated with steady-state modeling techniques based on the 1995 future wasteloads and the existing level of wastewater treatment. Three regionalization concepts were analyzed based on the conceptualized service areas developed for the basin. Additionally, a "baseline" simulation was performed to assess the effects of channel conditions, stream hydraulics, and background benthal loads. This is shown in Figure III-20.

The results of the initial segment analysis indicate that the future water quality during the 2 year-7 day low flow conditions, falls below the existing standards for dissolved oxygen. Specific problem areas, where D.O. falls below 5.0 mg/1, occur in the lower half of Cypress Creek below river mile 30.

Fecal coliform levels are projected to meet the 1983 water quality criteria of 200 MPN/100 ml, except for the theorized case where all future development in the basin is served by septic tank systems. Conceptual results of the segment analysis are presented in Table III-4 along with the initial evaluation of control themes. Except where otherwise noted, it is assumed that the majority of the future population is served by centralized treatment.

TABLE III-4

CYPRESS CREEK - SEGMENT ANALYSIS

Segment: 1009, low flow

Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
		D.O. (mg/1)	Fecal Coliform (MPN/100 ml)
All future wasteloads at existing effluent sets. No reduction of nonpoint source wasteloads	Existing technology	2.0	< 200
Reduce effluent load in problem areas. No reduction of nonpoint source wasteloads.	Increased treatment, land spread, interbasin transport, intrabasin transport.	3.0-3.8	< 200
Reduce effluent load in problem areas. Control nonpoint wasteloads to reduce benthic demand by 66%.	Increased treatment land spread, interbasin transport, intrabasin transport.	3.5-5.0	< 200

Additional conclusions developed in the segment analysis are:

1) Nonpoint source loads in the form of benthic oxygen demand are a major problem in the lower portion of the creek, especially in the area of river mile 20.

2) Other pollutants such as nutrients or conservative minerals do not present a problem.

3) Dissolved oxygen levels as low as 3.0 mg/1 and BOD levels as high as 10 mg/1 at the mouth of Cypress Creek produce no adverse effects in Spring Creek or Lake Houston.

Analysis of Themes:

Several wasteload control themes are available to meet the desired water quality goal as specified in the segment analysis.

The themes analyzed and their rejection or acceptance for additional study is presented below.

Theme	Description
1	Continue operation of existing plants at existing effluent sets. New population served by septic tank systems. This theme was rejected for further study because the future population cannot feasibly be served by septic tanks.
2	Continue operation of existing plants at existing effluent sets. Construct any new plants for operation at existing effluent sets. This theme was accepted for further study as the continuation of existing technology.
3	Reduce sewage effluent wasteloads by upgrading treatment efficiency to level 4NA. This theme was accepted for further study.
4	Reduce sewage effluent wasteloads by upgrading treatment efficiency to level 4NA and utilizing intrabasin transport of wasteloads from critical areas to areas with excess assimilative capacity. This theme was accepted for futher study.
5	Reduce sewage effluent wasteloads by upgrading treatment efficiency to level 4NA and utilizing interbasin transport of wasteloads from critical areas to the neighboring basin. This theme was accepted for further study.
6	Reduce sewage effluent wasteloads by upgrading treatment efficiency to level 4NA and utilizing land disposal of wasteloads from critical areas. This theme was rejected because land disposal is not considered feasible in the highly populated critical areas.

Discussion of Themes Evaluated

Theme 2 is a continuation of the existing level of technology for the stream segment. By definition, Theme 2 produces Water Quality Level I in the stream segment (D.O. = 2.0 mg/l and fecal coliform <200 MPN/100 ml). The cost associated with Theme 2 is indicative of the cost for providing sewage treatment to the existing and future projected population in the basin without regard to the desired water quality defined by levels II and III.

Theme 3 requires all sewage treatment plants in the basin to be upgraded from effluent set 2N to effluent set 4NA, except for those plants in geographical planning areas CY-1 and CY-2.

Theme 4 calls for intrabasin transport of wasteloads from a critical area of the stream to an area with excess wasteload capacity. Theme 4 requires all sewage treatment plants to operate at the same effluent set as described in theme 3. Wasteloads originating in geographical planning areas CY-3 through CY-7 would then be transported to CY-8 where they would be discharged to the stream.

Theme 5 calls for interbasin transport of wasteloads from critical stream sections to a waterway outside of the Cypress Creek drainage basin. Wasteloads originating in geographical planning areas CY-3 through CY-7 and CY-13 through CY-15 will be treated to effluent set 2 and then discharged to a tributary of Greens Bayou. The remaining treatment plants in the basin will receive the same treatment as described in Theme 3.

Themes 3, 4, and 5 all require implementation of controls and strategies that will result in improved water quality. However, the segment analysis simulation modeling projects the improved water quality to still fall short of the defined fishable/swimmable criteria for dissolved oxygen defined for the basin. Part of the reason for the dissolved oxygen deficit is the high benthal demand exhibited in the stream segment. The benthal demand values reported for Cypress Creek and utilized in the segment analysis and control themes are presented in Table III-5.

Based on information supplied by the TDWR, upgrading the existing level of sewage treatment to effluent set 4 (or better) will not only reduce the total wasteload to the stream, but will also reduce the benthal load to near background conditions, a reduction of approximately two thirds. The anticipated benthal reduction is attributed to the reduced level of biological sludge solids discharged to the stream from the treatment plants.

Point source wasteloads and nonpoint source wasteloads both contribute to the total benthal load. At the present time, the proportion of the existing benthal load attributable to biological solids from sewage treatment plants has not been identified. Therefore, the actual benthal load reduction due to upgrading of sewage treatment plants may or may not achieve the predictions of the TDWR.

TABLE III-5

COMPARISON OF CYPRESS CREEK BENTHAL DEMAND VALUES[1]

Stream	TDWR Model Calibration Run		TDWR Modeling Report Values		Literature Values Supplied by TDWR[2]		Values Used in Segment Analysis[3]		Values Predicted In Control Themes[4]	
Reach	20°C	29.4°C	20°C	29.4°C	20°C	29.4°C	20°C	29.4°C	20°C	29.4°C
1	0	0	0	0	225	405	760	1370	225	460
2	0	0	0	0	225	405	760	1370	225	460
3	0	0	0	0	225	405	760	1370	225	460
4	800	1450	760	1375	230	415	760	1370	225	460
5	2000	3615	1965	3550	340	615	1965	3550	620	1120
6	500	905	490	885	681	1230	490	890	165	300
7	2500	4520	2485	4490	681	1230	2485	4490	800	1450
8	1500	2710	1585	2865	1150	2080	1585	2870	530	960

1 All temperature corrections are based on: $B_t = B_{20} (1.065)^{T-20}$.

2 Based on 46 $mgO_2/ft.^2$-day. An average value for background level in sandy bottom streams.

3 Values selected consistent with TDWR Modeling Report.

4 Based on a two-thirds reduction due to control theme implementation.

Although implementation of Themes 3, 4, or 5 do not on their own achieve the desired water quality, when combined with the predicted two-thirds reduction in the benthal load, the fishable/swimmable water quality criteria is met.

Themes 3, 4, and 5 are evaluated for the semi-regional concept but are equally applicable to the regional and nonregional concepts. The costs associated with Themes 3, 4, and 5 include the cost to provide sewage treatment facilities to the present and projected population of the basin, plus the cost to achieve the desired water quality criteria.

Table III-6 presents the themes/concepts evaluated, the level of water quality achieved, and the estimated present worth costs for implementation.

TABLE III-6

COMPARISON OF THEMES/CONCEPTS
CYPRESS CREEK

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
2	Nonregional (A)	I	49	$44,100,000
2	Semi-regional (B)	I	5	31,300,000
2	Regional (C)	I	3	31,900,000
3	Semi-regional (B)	III	5	36,000,000
4	Semi-regional (B)	III	5	35,600,000
5	Semi-regional (B)	III	5	33,900,000

The stream segment profiles depicting BOD and D.O. concentrations for the themes/concepts described are presented in Appendix B , Figures III-21 through III-29.

Results of Wet Weather Segment Analysis

The WRECEV Water Quality Simulation Model is utilized for the wet weather segment analysis, as discussed in Chapter II. The simulation is applied over a twenty day period with the storm occurring in the first hour of the sixth day. Outputs are recorded for various time intervals at 24 junctions in Cypress Creek.

Currently, no standards exist specifically for wet weather situations. Therefore, the initial evaluation of resultant water quality is based upon dry weather standards.

Two simulations are performed with variations made in the point source wasteloads. The initial run is made with future point source wasteloads based upon presently permitted values as allocated in the Wasteload Evaluation Report. A second run is made with future point sources based upon one of the dry weather alternative technical subplans to verify that the initial simulation is representative of the results obtained with a dry weather technical subplan.

Figure III-30 presents the steady-state water quality conditions immediately before the storm. Figures III-31 through III-42 show the stream's response to the storm every two hours during the day of the storm's occurrence. Dissolved oxygen never drops below 6.0 mg/l. Data for the remaining days after the storm indicate that dissolved oxygen levels continuously increase throughout the period of simulation until reaching the steady-state conditions of 7.5 to 8.0 mg/l. Thus, based upon this data, wet weather conditions are well above the dry weather standard for Cypress Creek of 5.0 mg/l.

Fecal coliform concentrations are also indicated on Figures III-30 through III-42. The graphs show peaks in concentrations immediately after the storm that level out to approximately 1,000 MPN/100 ml in the upper reaches and 5,000 MPN/100 ml in the lower reaches by the end of the day of the storm.

To determine if the simulated wet weather conditions meet dry weather standards for fecal coliform, the definition of the standards is first examined. The 1983 fishable, swimmable standards as directed by the TDWR for Cypress Creek state that both of the following two cases must be met:

1) The geometric mean of fecal coliform concentrations recorded over 30 days must not exceed 200 MPN/100 ml.

2) Ten percent of the recorded samples must not exceed 400 MPN/100 ml.

For wet weather conditions on Cypress Creek, the junction exhibiting the peak concentration is also the junction exhibiting the longest lingering high concentration. Figure III-43 shows the change in levels of fecal coliform at Junction 17 throughout the time period simulated by the model. An additional ten days of data to complete the thirty day period was obtained by extrapolating between the concentration on the last modeled day and the steady-state conditions assumed to be reached by the thirtieth day. The geometric mean of these points is less than 100 and, therefore, well within the first condition of the standards.

The concentrations remain above 400 MPN/100 ml, however, for almost four days or thirteen percent of the period. This slightly exceeds the percent allowed under dry weather standards. Junctions 7 through 12 and 17 through 22 also remain above 400 MPN/100 ml for three to four days.

Based upon the inputs to the water quality simulation model for the design storm, wet weather conditions on Spring Creek are well within dry weather standards for dissolved oxygen. The condition of the fecal coliform standards that the geometric mean of the concentrations over a thirty day period remain less than 200 MPN/100 ml is also consistently met. However, the condition of an allowable ten percent of the points in excess of 400 MPN/100 ml is violated at several junctions, indicating that lingering high fecal coliform concentrations may create potential problem areas during wet weather conditions.

An additional analysis is performed to compare the total annual loadings of suspended solids from point sources and nonpoint sources. The Nonpoint Source Report identifies the total loadings of suspended solids to each basin per year. These total nonpoint source loadings are compared to the total point source loadings from the recommended dry weather alternative technical subplan. The total annual loading of suspended solids from nonpoint sources is reported at 98,000 tons while suspended solids from point sources is estimated at 120 tons per year.

The major portion of suspended solids enter through stormwater runoff, resulting in very high concentrations during wet weather conditions. These high concentrations may damage the aesthetic appeal of the Creek and contribute to benthal demands.

At this time, the information is not available to indicate the amount of harm caused by suspended solids. However, should suspended solids be found to create serious problems on Cypress Creek, controls on nonpoint sources should be considered.

Discussion

Utilizing existing levels of treatment and presently observed benthic demand, the simulated water quality of Cypress Creek is projected to not meet fishable/swimmable standards during critical dry weather flow. The water quality simulation is based on an unverified model. During the critical storm, Cypress Creek is projected to meet fishable/swimmable standards, except for minor variations from the fecal coliform standard.

In order to meet fishable/swimmable standards during dry weather, two actions are required: Benthic demand rates must be lowered by approximately two-thirds and point source waste loads must be reduced.

Simulation has shown that water quality criteria cannot be met without benthic load reductions. Presently, little is known concerning the actual benthic load, what is contributory to it, and how it can be controlled. A study is recommended to ascertain these factors and determine how reductions can be achieved and what amount of reduction can be expected. Because of the questions involved and the importance of this data, upgrading of treatment facilities without benefit of the benthic study in inappropriate.

The reduction of wasteload can be achieved by upgrading existing plants and building future plants at Effluent Set 4NA. Another alternative investigated is to construct some plants at Effluent Set 2 and transport effluent from those plants of the Cypress Creek Basin. Although the interbasin transport plan is the more economical, it is not selected as the preferred plan because:

- The political feasibility is in question.
- Regionalization will be required to spread costs and to construct cost effective interbasin transport systems.

Reducing the wasteloads to Effluent Set 4NA will, if benthic demand can be reduced by two-thirds, achieve fishable/swimmable water quality. While the majority of plants must be Effluent Set 4NA, certain plants, primarialy in the unpopulated upstream areas, can be Effluent Set 2N. Additionally, it is likely that individual small plants in the populated area can remain at Effluent Set 2N, but this has been rejected because it would create regulatory problems and would require a mechanism for cost spreading and regular re-evaluation of land use projections that presently does not exist.

Based on the above, the selected plan is to upgrade existing facilities to, and build future facilities for, Level 4NA with exceptions only in upstream unpopulated areas. However, such upgrading and high levels of treatment should not be required until the benthic study is complete. As a safeguard towards the likely eventual 4NA requirement, new construction should be required to show a plan for upgrading to 4NA.

Significant cost savings are inherent in regionalization in the Cypress Creek basin. Therefore, regionalization should be actively pursued and implemented where feasible.

Remarks on chlorine presented for Spring Creek also apply to Cypress Creek. While effluent ammonia is not important in Cypress Creek (since ammonia requirements are a portion of the permit), the action of ammonia in the stream is improtant and should be addressed in updating the steady-state model.

The high water quality projected during wet weather in Cypress Creek indicates that no definitive action need be taken to control the wet weather pollutants except to encourage Best Management Practices. However, the validity of the projection methods should be verified by wet weather water quality monitoring. Emphasis should be placed on:

- Dissolved oxygen concentrations.
- Ratios of total coliforms to fecal coliforms.
- The indication of lingering high fecal coliform counts.

Conclusions and Recommendations

1) Conduct benthic studies on Cypress Creek to determine the following:
   (i) The actual benthal demand along the creek.
   (ii) The relationship between sewage treatment plant discharge of biological solids and benthal demand. This can be accomplished by measuring the benthal demand upstream and downstream of various treatment plants.
   (iii) The relationship between the level of sewage treatment and benthal demand. This can be accomplished by comparing the benthal demand downstream of various treatment plants and correlating the results to the level of treatment produced by the respective plant.

2) Construct new plants at Effluent Set 2N but require that the provisions to upgrade to 4NA be shown.

3) Upgrade plants to 4NA if warranted by the results of the benthic study.

4) Actively pursue regionalization.

5) Consider placing maximum chlorine residual levels in permits.

6) Update steady state model with emphasis on the action of nitrogenous oxygen demand.

7) Implement wet weather water quality monitoring

8) Encourage the use of Best Management Practices.

Lake Houston

General Description of Area

Lake Houston is located approximately fifteen to twenty miles northeast of Houston. Major tributaries to the Lake include East and West Forks of the San Jacinto River, Spring Creek, Coney Creek, Peach Creek and Luce Bayou. Water is released through the Lake Houston Dam into the San Jacinto River. The drainage area served by the Lake consists of 2,828 square miles.

The Lake, which is owned and operated by the City of Houston, was built for a water supply. Though the Lake is used mainly for municipal water supplies, it also provides water for industry mining, irrigation, and recreational purposes.

Development around the Lake has not been extensive. However, since the area around Houston is undergoing rapid growth, development is projected to involve areas nearer the Lake. The basin's total population that will be served by municipal treatment plants is projected to be 40,700 by 1995.

Results of Dry Weather Segment Analysis

The segment analysis is performed on Lake Houston utilizing the simplified balance model discussed in the methodology section. Direct discharges to the Lake include only a few domestic wastewater treatment plants, all of which are located along the upper western arm of the Lake. Several existing plants have "no discharge" permits by which all treated effluent is retained and disposed of by evaporation and/or irrigation of grasslands. A septic tank code has also been imposed by the City of Houston that controls the location and type of construction used for septic tanks near the Lake. No industrial discharges are projected during the planning period.

The basin is divided into two geographical planning areas by the methods discussed previously. The location of each area and the manner in which they are combined for the concepts of semi-regionalization and regionalization are indicated on Exhibits III-2 through III-4.

The water quality levels addressed for Lake Houston are listed in Table III-7.

TABLE III-7

WATER QUALITY LEVELS
LAKE HOUSTON

Level	D.O. (mg/l)	Fecal Coliforms (MPN/100 ml)
I	As available from existing permitted effluent sets	As available from existing permitted effluent sets
II	5.0	$<$ 200
III	5.0	$<$ 20

Water quality for Lake Houston is simulated based on the 1995 projected wasteloads and the existing level of permitted wastewater treatment. The results of the initial dry weather segment analysis indicate that the dissolved oxygen level in Lake Houston will remain greater than 5.0 mg/l during the defined dry weather condition.

An additional segment analysis was performed utilizing only 20 percent of Lake Houston's capacity in order to estimate the water quality of the west fork where the majority of point source wasteloads originiate. The results of the second segment analysis also indicate that Lake Houston will maintain a dissolved oxygen concentration greater than 5.0 mg/l.

Other conclusions developed in the segment analysis are:

1) fecal coliform levels are projected to remain below 20 MPN/100 ml

2) for dry weather conditions, nonpoint source wasteloads are not significant

3) conservative minerals do not present a problem in Lake Houston

4) eutrophication may be a problem in Lake Houston

Analysis of Themes

The water quality in Lake Houston is projected to meet or exceed Water Quality Level III, the fishable/swimmable goals. Therefore, only nutrient loadings remain as a potential problem and are considered in the development of control themes.

The themes to be evaluated are as follows:

Theme	Description
1	Continue operation of existing plants discharging directly into Lake Houston at the presently permitted level. Construct any future plants discharging directly into Lake Houston for operation at the presently permitted level.
2	Continue operation of all existing plants discharging within the Lake Houston drainage basin (Spring Creek, Cypress Creek, and Lake Houston) at their presently permitted level. Construct any future plants discharging within the Lake Houston drainage basin for operation at the existing permitted level.
3.	Upgrade all existing plants discharging within the Lake Houston drainage basin to include phosphorus removal. Construct any future plant discharging within the Lake Houston drainage basin for operation at the presently permitted level plus phosphorus removal.

Discussion of Themes Evaluated

Since the projected water quality in Lake Houston meets or exceeds the fishable/swimmable criteria for dissolved oxygen and fecal coliform, defined by level III, the themes evaluated deal only with nutrient concentrations.

Theme 1 is a continuation of the existing level of permitted treatment for municipal plants discharging directly into Lake Houston. The cost associated with Theme 1 is indicative of the cost for providing the presently permitted level of sewage treatment services to the existing and future population in the Lake Houston geographical planning areas without regard to improved water quality.

Themes 2 and 3 are concerned with nutrient control within the greater Lake Houston drainage basin. Theme 2 is a continuation of the existing standard with total phosphorus concentrations from uncontrolled point sources estimated at 10.0 mg/l. Theme 3 calls for control of phosphorus to a concentration of 2.0 mg/l for all point sources discharging into Spring Creek, Cypress Creek, or Lake Houston. Themes 2 and 3 result in a total annual phosphorus loading to Lake Houston from point source discharges of approximately 445 tons and 90 tons respectively.

The costs associated with Theme 2 and 3 are a comparison of the costs associated with phosphorus control for all sewage treatment plants discharging into the Lake Houston 208 drainage basin. Table III-8 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE III-8

COMPARISON OF THEMES/CONCEPTS
LAKE HOUSTON

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional (A)	III	10	$ 6,800,000
1	Semi-regional (B)	III	2	6,900,000
1	Regional (C)	III	1	8,500,000
2	Nonregional (A)	III		72,600,000
3	Nonregional (A)	III		86,400,000

In March 1977, EPA in cooperation with the TWQB published an evaluation report on Lake Houston. In the report, a loading of 0.48 grams/square meter-year was identified as the "permissible" total phosphorus loading that would result in Lake Houston remaining oligotrophic. This relates to a total load of approximately 26 tons/year. The report further identified 170 tons/year of total phosphorus originating from nonpoint sources.

The Nonpoint Source Analysis reports that approximately 30 tons/year of phosphorus is identified as originating in the Spring Creek/Cypress Creek/Lake Houston drainage basin. Therefore, approximately 140 tons of phosphorus from nonpoint sources originates from outside the 208 planning area.

The annual phosphorus loading contributed from outside the 208 area is well in excess of the permissible 26 tons/year necessary to control eutrophication. Therefore, controlling point source contributions of phosphorus without controlling the nonpoint source contributions from both inside and outside the 208 area will probably not produce any significant benefits.

Results of Wet Weather Segment Analysis

The Nonpoint Source Analysis Report identifies 199,000 tons/year of suspended solids, 4,700 tons/year of BOD, 200 tons/year of nitrogen, and 30 tons/year of phosphorous entering Lake Houston through nonpoint sources originating in the Spring Creek/Cypress Creek/Lake Houston drainage basin. The report further indicates that urban runoff is the major source of suspended solid and BOD wasteloads in the basin while agricultural runoff is the major contributor of fecal coliform.

Except for total phosphorus as discussed in the dry weather segment analysis there is no information concerning the additional wasteloads originating from outside the 208 area. Due to the agricultural nature of the land outside the 208 area, it is anticipated that suspended solids and BOD will not present a major problem to Lake Houston while high fecal coliform counts may present a potential problem.

Discussion

No water quality simulation models are available for Lake Houston. A nonspecific lake model was used to analyze this body of water. Based on this model, water quality is projected to meet fishable/swimmable standards with plants in the drainage basin continuing to operate at existing permitted Effluent Sets. While there is some small incentive to regionalize, the projected land use patterns do not greatly favor the regional concept. Reevaluation will be necessary as new land use patterns emerge. The need for phosphorus removal from point source discharges was also evaluated. The phosphorus loading from nonpoint sources both within and without the Study Area, is significantly higher than the level necessary to prevent eutrophication of the Lake and, therefore, the benefit of phosphorus controls on point sources is questionable. A detailed eutrophication study would be necessary to ascertain any benefits of phosphorus removal.

Chlorine residuals are not believed to be a problem in the Lake. No wet weather model is available for Lake Houston. However, based on the Spring Creek and Cypress Creek results, no wet weather problem is anticipated. Therefore, no definitive wet weather controls are necessary for wet weather except to encourage the use of Best Management Practices.

Conclusions and Recommendations

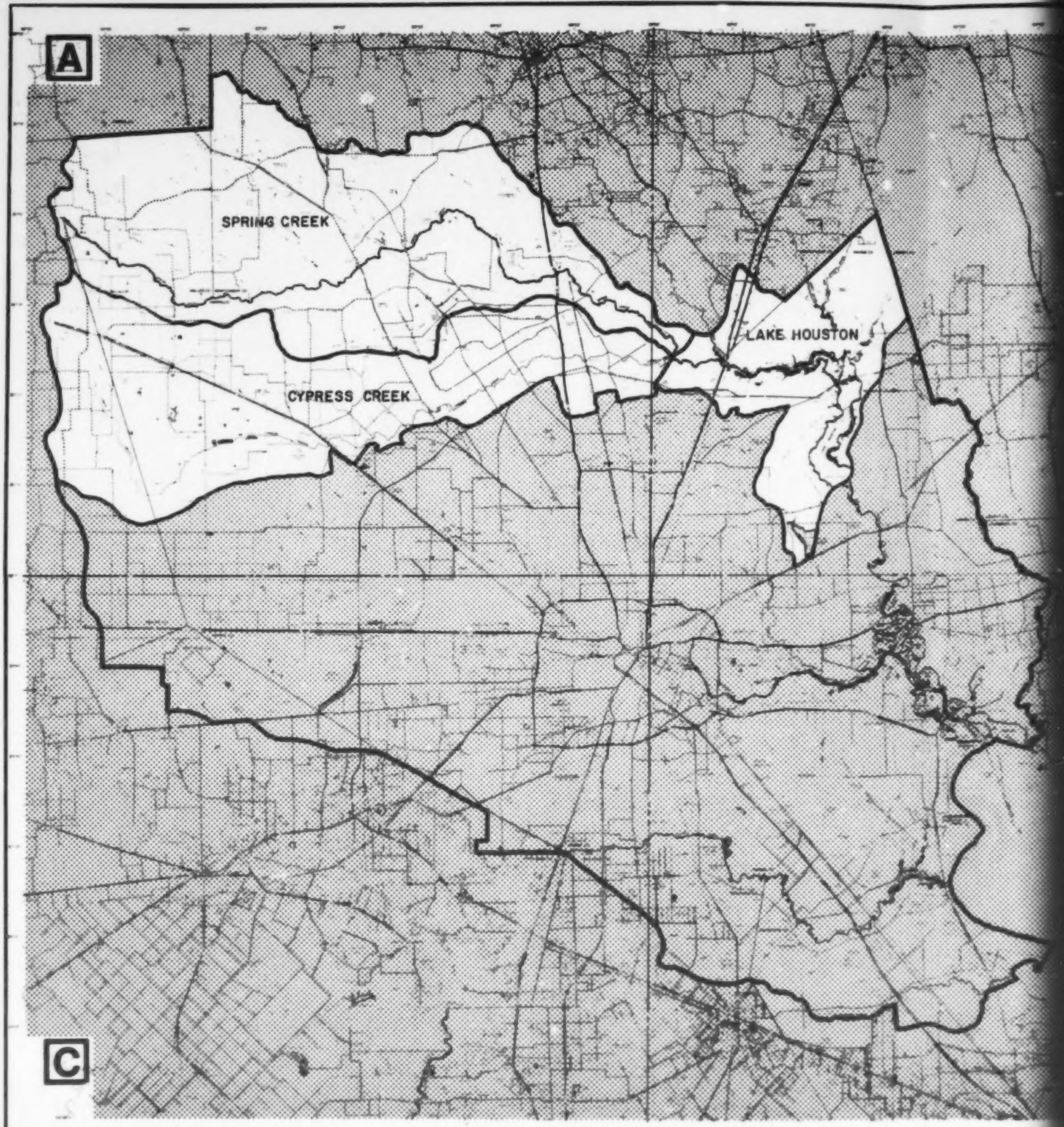
1) Continue operating existing and future treatment plants at presently permitted levels.

2) Perform eutrophication study.

3) Do not institute phosphorus controls.

4) Evaluate regionalization as new land use patterns emerge.

5) Encourage the use of Best Management control practices.


A
SPRING CREEK
CYPRESS CREEK
LAKE HOUSTON
C

— 208 PLANNING AREA

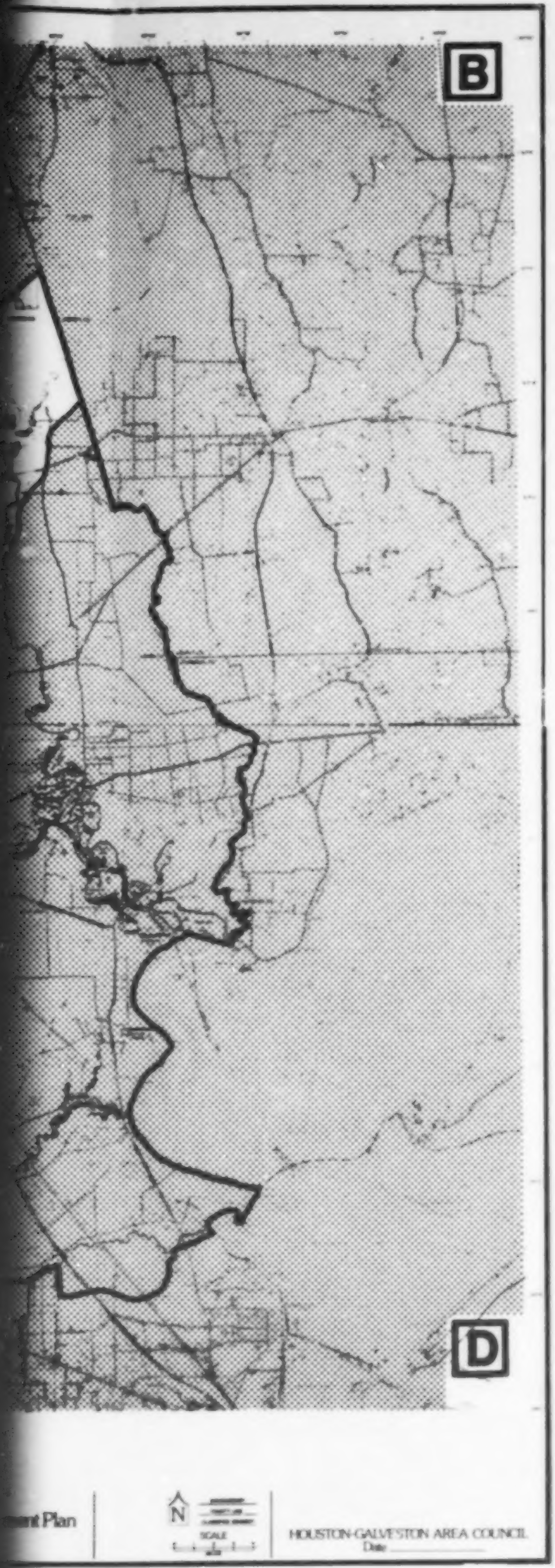
— DRAINAGE BASINS

KEY

A	B
C	D

Areawide Waste Treatment Management Plan
HOUSTON AREA

N


B
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HOUSTON-GALVESTON AREA COUNCIL
Date

GREATER HOUSTON 208 PROGRAM

HOUSTON-GALVESTON AREA COUNCIL

SPRING CREEK/CYPRESS CREEK/LAKE HOUSTON

TECHNICAL SUBPLANNING AREA

DRAWN BY: ROY F WESTON DATE:	REVISIONS BY: DATE:	EXHIBIT III-1 SCALE SECTION

CHAPTER IV - CLEAR CREEK/CLEAR LAKE

CHAPTER IV - CLEAR CREEK/CLEAR LAKE

Introduction

The Clear Creek/Clear Lake technical subplanning area is located in the southeast quadrant of the 208 planning area (see Exhibit IV-1. The area has experienced major development in the last five years and is projected to continue this trend throughout the planning period. The water courses of concern in this area include Clear Creek (both tidal and nontidal portions), Clear Lake, Dickinson Bayou (both tidal and nontidal portions), and Armand Bayou.

Clear Creek Nontidal

Description of Area

Clear Creek (nontidal segment) is located approximately 12 miles south of downtown Houston. It flows east forming the boundary between Harris County and Brazoria County. The nontidal portion of Clear Creek flows approximately 31 miles from its headwaters in eastern Fort Bend County prior to entering the tidal portion of Clear Creek at FM 528. Major tributaries within the study area include Cowart Bayou, Turkey Creek, Mary's Creek, Mud Gully, and Hickory Slough. The total basin population that will be served by municipal treatment systems is projected to be 88,200 by 1995.

Results of Dry Weather Segment Analysis

The QUAL-II Water Quality Simulation Model calibrated by the TDWR, but not yet verified, is utilized for the dry weather segment analysis. Four of Clear Creek's major tributaries are also simulated in the model.

The nontidal portion of Clear Creek is divided into three geographical planning areas. The location of each area and their relationship to various regionalization concepts is indicated in Exhibits IV-2 through IV-4.

The water quality levels addressed for this stream segment are listed in Table IV-1.

TABLE IV-1

WATER QUALITY LEVELS
CLEAR CREEK - NONTIDAL

Level	D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
I	As available from modified effluent set 3NP.	As available from modified effluent set 3NP.
II	5.0	< 2,000
III	5.0	< 200

The permitted effluent level for Clear Creek is referred to as a modified 3NP. The difference is that the suspended solids level for the Creek is permitted at 12 mg/l rather than 10 mg/l as defined by level 3NP.

Water quality for Clear Creek nontidal is simulated based on the 1995 projected wasteloads and the existing level of wastewater treatment. Three regionalization concepts are analyzed based on the geographical planning areas developed in the basin. Additionally, a "baseline" simulation is performed in order to determine the effects of channel conditions, stream hydraulics, and background benthal loads (see Appendix B, Figure IV-1).

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration of approximately 2.0 mg/l at the critical points in the stream. Projected levels of fecal coliform remain below 200 MPN/100 ml. As expected, critical points in the stream occur downstream of major point source discharges and at the mouth of the segment where stream hydraulics are affected by tidal conditions.

Conceptual results of the segment analysis are presented in Table IV-2 along with the initial evaluation of pollution control themes. Except where otherwise stated, it is assumed that the majority of the future population is served by centralized treatment systems as opposed to septic tank systems.

TABLE IV-2

CLEAR CREEK NONTIDAL SEGMENT ANALYSIS

Segment: 1102, low flow

Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
		D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
All future wasteloads at effluent set 3NP	Existing Technology	2.0	<200
Reduce wasteload to stream in order to meet Water Quality Levels II & III	Increase level of effluent treatment, interbasin transport, land disposal	5.0	<200

Additional conclusions developed in the segment analysis are:

1) For dry weather conditions, nonpoint source wasteloads are not significant.

2) Nutrient loading into Clear Creek does not present a problem in the nontidal portion. However, the nutrients contribute to the overall loading in Clear Lake which has a potential nutrient problem. This is further covered in the Clear Lake portion of this report.

Analysis of Themes

Several wasteload control themes are available to meet the desired water quality as specified in the segment analysis. The themes analyzed and their rejection or acceptance for additional study is presented below.

Theme	Description
1	Continue operation of existing plants at modified effluent set 3NP. New population served by septic tank systems. This theme was rejected for further study because the future projected population cannot feasibly be served by septic tanks.
2	Continue operation of existing plants at modified effluent set 3NP. Construct new plants for operation at modified effluent set 3NP. This theme was accepted for further study as the continuation of existing technology.
3	Reduce sewage effluent wasteloads by upgrading treatment efficiency to level 4NPA. This theme was accepted for further study.
4	Reduce effluent wasteload by upgrading effluent treatment to level 4NPA and utilizing land disposal techniques for major discharges. This theme was accepted for further study.
5	Reduce effluent wasteload by utilizing inter-basin transport of major dischargers and upgrading remaining effluent treatment to level 4NP. This theme was accepted for further study.

Discussion of Themes Evaluated

Theme 2 is a continuation of the existing level of technology for the stream segment. By definition, Theme 2 produces Water Quality Level 1 in the stream segment (D.O. = 2.0 mg/l and fecal coliform < 200 MPN/100 ml). The cost associated with Theme 2 is indicative of the costs for providing sewage treatment to the existing and future projected population in the basin without regard to the desired water quality defined by levels II and III.

Theme 3 requires implementation of controls and strategies that will result in improved water quality. However, the segment analysis simulation predicts the improved water quality dissolved oxygen to still be less than the defined fishable/swimmable standard for the last 6 miles of the segment. A portion of the total oxygen deficit is due to the contribution created by the benthic load in the stream segment.

As described in Chapter III ("Discussion of Themes Evaluated" for Cypress Creek), upgrading the existing level of sewage treatment is anticipated to create a reduction in the benthal load. The benthal demand values reported for Clear Creek nontidal and utilized in the segment analysis are presented in Table IV-3.

Although implementation of Theme 3 does not achieve the desired water quality, when combined with the predicted reduction in benthal load, the dissolved oxygen level in the segment reached 4.5 mg/l at the critical point and the goal of fishable/swimmable water quality is nearly achieved.

Theme 4 is based on utilizing land disposal techniques in geographical planning area CL-2, during dry weather conditions only. During average flow conditions ($Q > 30$ CFS) wastewater from CL-2 would be discharged directly to the stream. Effluent would require treatment equivalent to effluent set 2 prior to land disposal and treatment to effleuent set 4NA prior to discharge into Clear Creek in order to achieve the desired water quality. Theme 4 would be a difficult and costly treatment system to operate and therefore has not been fully evaluated.

Theme 5 requires implementation of controls and strategies that will result in achieving Water Quality Level III. In the case of Clear Creek nontidal, Water Quality Level II has the same dissolved oxygen criteria as level III. Since fecal coliform present no problems during dry weather, the controls and strategies of Theme 5 are also required to achieve Water Quality Level II. Theme 5 was evaluated for the semi-regional concept but is equally applicable to the nonregional and fully regional concepts. Theme 5 calls for upgrading of effluent treatment from sewage treatment plants in geographical planning area CL-1 to level 4NP and interbasin transport of sewage treatment plant effluent in geographical planning area CL-2 to a tributary of the Houston Ship Channel.

The cost associated with Theme 5 includes the cost to provide sewage treatment to the projected population plus the cost to obtain the desired water quality criteria (D.O. = 5.0 mg/l and fecal coliform < 200 MPN/100 ml).

TABLE IV-3

COMPARISON OF CLEAR CREEK BENTHAL DEMAND VALUES[1]

Stream Reach	TWQB Model Calibration Run		TWQB Modeling Report Values		Literature Values Supplied by TWQB[2]		Values Used in Segment Analysis[3]		Values Predicted In Control Themes[4]	
	20°C	29.4°C	20°C	29.4°C	20°C	29.4°C	20°C	29.4°C	20°C	29.4°C
1	0	0	0	0	331	600	330	600	110	200
2	0	0	0	0	331	600	330	600	110	200
3	500	900	330	600	331	600	330	600	110	200
4	500	900	330	600	331	600	330	600	110	200
5	500	900	330	600	331	600	330	600	110	200
6	500	900	330	600	658	1190	330	600	110	200
7	500	900	330	600	658	1190	330	600	110	200
8	500	900	330	600	658	1190	330	600	110	200
9	500	900	330	600	437	790	330	600	110	200
10	500	900	330	600	442	800	330	600	110	200
11	500	900	330	600	658	1190	330	600	110	200
12	500	900	330	600	437	790	330	600	110	200
13	500	900	330	600	442	800	330	600	110	200
14	500	900	330	600	920	1660	330	600	110	200
15	500	900	330	600	331	600	330	600	110	200
16	500	900	330	600	331	600	330	600	110	200
17	700	1270	460	830	768	1390	460	830	155	275
18	700	1270	460	830	957	1730	460	830	155	275

[1] All temperature corrections are based on: $B_t = B_{20}\ (1.065)^{T-20}$.

[2] Based on 46 mg $O_2/ft.^2$-day. An average value for background level in sandy bottom streams.

[3] Values selected consistent with TWQB Modeling Report.

[4] Based on a two-thirds reduction due to control theme implementation.

The stream segment profiles depicting BOD and D.O. concentrations for themes/concepts described are presented in Appendix B, Figures IV-2 through IV-8.

Table IV-4 presents the themes/concepts evaluated and the estimated present worth costs for implementation

TABLE IV-4

COMPARISON OF THEMES/CONCEPTS
CLEAR CREEK - NONTIDAL

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
2	Non regional (A)	I	10	$21,000,000
2	Semi-regional (B)	I	2	19,600,000
2	Regional (C)	I	1	19,300,000
3	Non regional (A)	III*	10	23,400,000
3	Semi-regional (B)	I	2	21,100,000
5	Semi-regional (B)	III	2	16,600,000

* Approaches Level III, projected D.O. = 4.5 mg/1.

Results of Wet Weather Segment Analysis

The WRECEV Water Quality Simulation Model is utilized for wet weather segment analysis, as discussed in Chapter II. The simulation is applied over a twenty day period with the storm occurring in the first hour of the sixth day. Wasteloads and stormwater flows for 1975, 1983, 1990, and 1995 conditions are input to the model at predefined time intervals in specified junctions. The model then simulates the resulting stream flow and water quality versus time.

Currently, no standards exist specifically for wet weather situations. Therefore, the initial evaluation of resultant water quality is based upon dry weather standards.

Two simulations for 1995 conditions are performed with variations made in the point source wasteloads. The initial run is made with future point source wasteloads based upon presently permitted values as allocated in the Wasteload Evaluation Report. A second run is made with future point sources based upon one of the dry weather alternative technical subplans to verify that the initial simulations is representative of the results obtained with a technical subplan.

Appendix B, Figure IV- 9 , presents the steady-state water quality conditions immediately before the storm. Appendix B, Figures IV-10 through IV-21 show the streams response to the storm event every four hours. Oxygen concentrations drop following the storm with most junctions falling below 5.0 mg/l within three hours. The middle to lower portions of the stream experience the lowest dissolved oxygen concentrations. Junction 9, as shown in Appendix B, Figure IV-22 , contains less than 1.0 mg/l for a ten hour period on the day of the storm. All portions of the stream have recovered to 5.0 mg/l within one and one-half days.

Fecal coliform concentrations are also indicated on Figures IV-9 through IV-22. The graphs show peaks in concentrations immediately following the storm. Decreases in concentrations occur gradually with levels remaining high for several days throughout the stream. The various junctions demonstrate concentrations above 200 MPN/100 ml (fishable/swimmable standards) for four to thirteen days after the storm. Junction 10 exhibits one of the highest peak concentrations (90,000 MPN/100 ml) as well as the longest lingering concentration as shown in Appendix B, Figure IV-23.

The simulations for the intervening years indicate a continual deterioration of water quality from present conditions throughout the planning period. The 1975 stormwater runoff wasteloads produce a resultant water quality that meets dry weather standards. Dissolved oxygen never drops below 5.0 mg/l in the segment and fecal coliform concentrations drop to allowable levels within several days (see discussion of fecal coliform standards in Chapter III, Spring Creek wet weather segment analysis).

1983 conditions indicate a decrease in water quality. Dissolved oxygen concentrations drop to 3.0 mg/l at one junction in the lower portion of the segment and 4.0 mg/l in the upper and middle portions. All parts of the segment have recovered to 5.0 mg/l dissolved oxygen within one day after the storm. Fecal coliform concentrations remain above fishable/swimmable standards for eleven to twelve days following the storm.

Wet weather water quality conditions in 1990 show a further deterioration from that observed in 1983. Dissolved oxygen falls below 2.0 mg/l in the lower portions of the segment and drops below 3.0 mg/l in other parts of the stream. Concentrations remain below 5.0 mg/l for slightly over one day following the storm. Fecal coliform concentrations linger at high levels for twelve to thirteen days after the storm.

An additional analysis is performed to compare the total loadings of suspended solids from point sources and nonpoint sources. The Nonpoint Source Analysis Report identifies the total loadings of suspended solids to each basin per year. These loadings for 1995 are compared to the total point source loadings for 1995 to all of Clear Creek based upon the alternative technical subplans. This information indicates that nonpoint sources contribute 58,500 tons/year while point sources contribute 100 tons/year.

Analysis of Themes

Based on the results of the segment analysis, future wet weather conditions on Clear Creek violate dry weather standards. To determine the need for runoff controls, the water quality necessary to preserve the water uses of the stream must be defined. Environmental information indicates that Clear Creek can be maintained as a fish and wildlife habitat with dissolved oxygen concentrations as low as 4.0 mg/l for short periods of time. Although this level of oxygen may hinder reproduction in some species, the fishlife can survive. However, dissolved oxygen concentrations of 3.0 mg/l or less may be detrimental to critical game fish in the stream.

As discussed in the results of the segment analysis, 1983 conditions produce a water quality of above 4.0 mg/l dissolved oxygen except in one junction of the stream. All portions of the stream have recovered to 5.0 mg/l within one day. Since the dissolved oxygen problem is localized to one area, the fishlife would temporarily migrate out of this area to an upstream portion of the stream until the oxygen level had recovered. Therefore, wet weather water quality in 1983 does not threaten the use of Clear Creek as a fish and wildlife habitat based upon dissolved oxygen concentrations.

The 1990 and 1995 conditions, however, result in water quality below 3.0 mg/l dissolved oxygen in many parts of the stream with some areas falling below 2.0 mg/l in 1990 and 1.0 mg/l in 1995. Since some species cannot survive in these conditions, controls on stormwater runoff for oxygen demanding materials will be necessary at some point in the 1983-1990 time frame.

Several simulations are made with reductions in the BOD wasteloads for 1995 conditions. It is determined that, based upon the results of the model, a fifty percent reduction results in a minimum dissolved oxygen concentration of 3.5 mg/l. With a seventy-five percent reduction in BOD wasteloads, dissolved oxygen concentrations never drop below 5.0 mg/l. Therefore, a fifty to seventy-five percent reduction in wet weather BOD wasteloads is needed by 1995.

The results of the segment analysis indicate high concentrations of fecal coliform lingering for many days after the storm in 1983, 1990, and 1995. If the stream is to be preserved for primary contact recreation, a large reduction in fecal coliform wasteloads will be required. "Swimmable" conditions as defined by the dry weather standards can be achieved for 1995 conditions by a 98 percent reduction in fecal coliform loads from stormwater runoff.

Once the amount of necessary reductions is defined, the source of the contributing wasteloads must be determined. Since present conditions do not produce a wet weather water quality problem, the deterioration of water quality in future years is the result of projected increases in runoff wasteloads. According to the Nonpoint Source Analysis Report the increase in BOD loads to the Clear Creek basin between 1975 and 1995 is attributable to urban runoff. BOD loads from urban runoff increase from 393 tons/year in 1975 to 580 tons/year in 1995. Changing land use patterns indicate almost a doubling of urban areas in the Clear Creek Non-tidal watershed and population projections call for a proportionate amount of growth. Agricultural loads as well as agricultural land use are projected to decrease slightly. Therefore, control strategies for wet weather conditions should be directed towards urban runoff.

The mass balance of suspended solids indicates that nonpoint sources account for the majority of suspended solids entering the stream. A large portion of this load enters through stormwater runoff, resulting in very high concentrations during wet weather conditions. These high concentrations may damage the aesthetic appeal of the Creek, increase the need for dredging in the Creek and Clear Lake, and contribute to benthal demands.

At this time, the information is not available to indicate the amount of harm caused by suspended solids. However, should suspended solids be found to create serious problems on Clear Creek, controls on nonpoint sources are recommended. According to the inputs to the simulation model, by controlling the first flush during the ten hours following the design storm, an 85 percent reduction in total suspended solids from that wet weather event can be obtained.

Evaluation of Categories for Urban Runoff Control

Many types of nonpoint source control strategies are available for reduction of the impact of urban runoff. A nonpoint source control program can include a wide range of techniques, varying from leash laws to centralized collection and treatment. Many factors must be considered in the selection of a suitable control. The Nonpoint Source Analysis Report has compiled a ranking of each general category of control strategies. This comparison is based upon the relative ecological, socio-political, socio-economic, and land use impacts as well as cost-effectiveness, feasibility, and applicability to the 208 area. According to this ranking procedure, vegetative control techniques are the most favorable method of control for urban runoff for the 208 area. Small scale retention is ranked as the second most suitable category of control strategies for urban runoff.

Vegetative control techniques provide for the maximization of vegetation covers which act as a natural method of abatement or treatment of runoff. The maintenance of a good vegetative cover provides maximum erosion prevention, thus reducing the possibility of sediment being dislodged and transported. By preventing sediment transport, the associated oxygen-demanding materials, nutrients, heavy metals, herbicides, and pesticides are also prevented from entering a waterway. A good vegetative cover also slows the velocity of runoff, thereby aiding in its detention and the reduction of peak runoff rates. Vegetation can act as a filter or screen, as well, to remove particles from suspension.

The simplest and most effective vegetative control technique is the conservation of natural vegetation in development projects. Besides preventing increases in runoff rate and runoff volume resulting from urbanization, secondary benefits include aesthetics, relative ease of implementation, and the relatively low cost of implementation and maintenance. The areas reserved for vegetation cover can be landscaped within the development project or occur as a common park type area located in a manner that allows the urban runoff to flow over it during wet weather conditions.

The only disadvantage of conserving natural vegetation is the increased land requirements. The need for additional land can be avoided by the cluster housing concept of residential development. The clearing of natural vegetation is minimized by the construction of small residential enclaves and multi-story housing. This concept, however, does not provide the privacy desired by most homeowners and cannot be completely applied to the 208 area.

Another type of vegetative control is the allowance for vegetation belts along the stream's banks. This concept is very compatible with current flood plain programs. By restricting development in flood plains, not only will flooding damage be limited but an additional benefit of nonpoint source wasteload reduction will be realized as well.

As discussed in the Nonpoint Source Analysis Report, vegetation is an important component of other types of control strategies. Swales, retention/detention ponds, sediment control basins, and infiltration basins all rely upon a vegetative cover to keep them operational.

Natural storage is provided during overland flow in surface depressions and on wetted vegetation. However, much natural storage is temporary, of small volume, and can be lost through development. This volume can be replaced by utilizing small scale retention techniques. One of the highest ranked small scale retention techniques is also dependent upon vegetation. "Blue-green belt" areas include a permanent runoff storage lake and grassy area in the natural drainage way. This type of control provides storage, peak flow attenuation, and some treatment to stormwater runoff, as well as providing an aesthetic "plus" to an area.

It should be noted that the effectiveness of storage lakes is heavily dependent upon adequate design. Good engineering design is necessary to set the area of the lake, the elevation of the overflow structure, and the storage capacity in order to achieve the desired pollutant removal. Such impoundments are also highly susceptible to pollution from the stormwater runoff they contain, accumulation of debris and floating trash characteristic of any inhabited area, and possible contamination from domestic sewage. Therefore, continual maintenance is required to keep the facilities in their expected condition.

Other small scale retention techniques providing temporary storage of runoff include parking lot ponding and rooftop storage. Although they can easily be incorporated into existing building design, parking lot design, and the planning of new shopping malls and developments, they are not ranked as high as other small scale retention techniques since they provide little or no treatment of the runoff.

One of the simplest forms of urban runoff wasteload reduction involves what can be described as "good housekeeping" techniques. These include such methods as street sweeping, good refuse collection, leash laws, and proper application of lawn fertilizers and pesticides. Although "good housekeeping" techniques may not provide the total amount of desired pollutant reduction, they require very little to no committment of resources, are easy to implement and, most importantly, can be applied to existing urban areas.

A multitude of other control strategies for urban runoff are available such as large scale retention, retention and conventional treatment, pumping by centralized treatment facilities, groundwater recharge, and assorted land drainage modifications. However, these techniques generally are expensive, require large committments of resources, are difficult to implement and maintain, or are not as effective in pollutant removal as those techniques previously discussed. The recommended control strategies for Clear Creek Nontidal watershed are, therefore, based upon vegetative control techniques, small scale retention, and "good housekeeping" methods.

Discussion of Themes Evaluated

The wet weather water quality problem in Clear Creek has been identified as resulting from urban runoff. The areas of heaviest urban growth according to the land use projections are in the Friendswood and Sagemont/Kirkwood/Scarsdale areas. The largest loadings in the simulation model also correspond to these general areas. Control strategies are, therefore, recommended for these two areas in the watershed.

It has also been determined, based upon the results of the simulation model, that a fifty to seventy-five percent reduction in BOD runoff loads and a ninety-eight percent reduction in fecal coliform runoff loads is necessary to preserve the water uses of the stream. Unfortunately, the effectiveness of nonpoint source controls is not well known at this time. One of the objectives of this report is to recommend control strategies based upon their estimated range of effectiveness and outline a follow-up monitoring program to document their effectiveness in the 208 area.

One of the most available mechanisms for implementing runoff control strategies in the 208 area is via subdivision plat approval. Two implementation approaches within subdivision plat approval exist: performance oriented controls or proscriptive controls. Performance controls specify the desired end product in terms of physical and chemical parameters. Performance standards for this basin would be the percentage BOD and fecal coliform reductions mentioned above. It is left up to the developer to choose the strategy for achieving this reduction. By contrast, proscriptive controls specify the use of certain types of processes within the development.

The advantages and disadvantages of the two approaches as presented in the supplement to the Nonpoint Source Analysis Report do not describe one approach as being more favorable than the other (performance standards enhance innovation and cost concerns, proscriptive controls are more easily administered). Therefore, it is suggested that the developer be given either option. If the proscriptive approach is chosen, the control strategies discussed below are recommended.

The first step in the urban runoff control program is to select an area that represents the typical form of development to provide baseline data. In other words, this area will serve as a "control" area. It will be monitored for runoff wasteloads without the implementation of control strategies for comparison to those areas where controls are applied. All of the test areas should be selected based upon their typicality, minimum size, and minimum economic and social disruption.

A test area is suggested to document the effects of "good housekeeping" techniques. Recommended control strategies are street sweeping and good refuse collection programs including proper garbage disposal and picking up yard trimmings and other litter. Although it is doubtful that this program alone can provide the necessary load reductions, it is an important control category due to its ease of implementation in existing developed areas.

Three test areas for vegetative control techniques are recommended. Since this watershed currently has an abundance of vacant and pasture lands, it should be possible to locate a developed area where something resembling the use of vegetative techniques presently exists, This area can be sampled simultaneously with the "control" area to give a preliminary comparison of the effectiveness of the vegetation cover. Another area alloting an extra amount of land for a vegetative cover within the development is recommended, as well as an area that allots an extra amount of land for a vegetation belt in the drainage way outside the development. According to the Nonpoint Source Analysis Report, the conservation of natural vegetation may provide over a fifty percent reduction in oxygen demanding materials and up to a ninety-nine percent reduction in pathogens. Thus, it is possible that the maintenance of a good vegetative cover will provide the desired reduction in runoff pollutants.

The final suggested test area includes the use of a small scale retention technique. The "blue-green" concept of a grassy area followed by a runoff storage lake is ranked as most effective and implementable. Depending on the size of the storage lake, this control strategy is estimated to provide a twenty-five to fifty percent reduction in oxygen demanding pollutants. Pathogen reduction, however, is negligible. Due to land requirements, vegetative control techniques and the "blue-green" concept will be most applicable to future developments.

The implementation of a continuing monitoring program serves a dual purpose: to document the effectiveness of runoff control strategies, as well as to verify the simulation model and its inputs. The stormwater modeling effort is one of the first approaches to wet weather water quality in Clear Creek and should be considered as the basis for futher study. All results are dependent upon the inputs to the model which have not been verified. Particular attention should also be directed towards the ratio of total coliform to fecal coliform. As discussed in the wet weather segment analysis methodology, the results are based upon an assumed ratio.

Since the wet weather water quality problem is projected to begin within the 1983 to 1990 time frame for dissolved oxygen levels and between the present time and 1983 for fecal coliform concentrations, the application of control strategies must be planned for as soon as possible. The control strategies require additional amounts of land which must be reserved now in future developments. With these objectives in mind, the following steps are recommended for immediate implementation:

1) Select the test areas.

2) Perform background sampling in the test areas as well as other areas to be sampled for model verification. Simultaneously begin verification of the model.

3) Based upon verification of the model, implement development policies requiring allotment of sufficient land for vegetative control techniques and small scale retention.

4) Implement the described control techniques in the test areas.

5) Monitor the effectiveness of the control techniques.

6) Implement the effective techniques.

If none of the recommended control strategies provide the desired reductions in runoff loads, more expensive controls will be necessary. Most of these controls will also have additional land requirements and can be constructed in the previsouly reserved areas. Therefore, each of the implementation steps provides a constructive step towards a nonpoint source control program.

Discussion

The Clear Creek nontidal segment is projected to have a water quality problem during both the critical dry weather conditions and the design storm conditions. This conclusion is based on the results of the simulation models previously discussed.

Some of the modeled inputs are based on textbook, literature, or assumed values and therefore, need to be verified as part of the implementation or continuing planning process. Of specific importance to the Clear Creek drainage basin are the following items which impact on the water quality simulations, the alternatives evaluated and the preferred technical subplan.

1) The oxygen demand and reaction rate due to nitrification.

2) The stormwater related oxygen demanding wasteload inputs and response to the model.

3) The stormwater related fecal coliform levels.

Other items which, although they do not impact on the water quality simulation model, do effect the alternative technical subplans include the cost/benefits of phosphorus removal in the Clear Lake drainage basin, and the political/social aspects of interbasin transport. A discussion of phosphorus removal is contained in the Clear Lake section.

Of the alternative technical subplans evaluated, interbasin transport of treated wastewater is the only method of achieving the stated water quality goals. Some of the negative aspects of this alternative are the effects of the additional wasteload on the intermediate receiving streams and the effect of increasing the wasteload to the Houston Ship Channel. There are also positive aspects of this alternative. The plan is technically feasible. The plants in question are all operated by the City of Houston, which has the resources to fully evaluate and implement the plan. Additionally, there are indications that financial savings are to be gained since a lower level of sewage treatment would be required for those plants utilizing interbasin transport.

Although there are indications that some level of regionalized sewage treatment may provide financial incentives (i.e., economy of scale, etc.), the nonregional concept is recommended as part of the preferred plan. The major obstacles to a regionalized system is the rapid development of the area combined with the lack of an overall management system (except for City of Houston treatment plants) to fully develop, operate, and control a regionalized sewage treatment system. The management system developed as part of the 208 program will, in time, be able to respond to the needs and economics of a regionalized treatment system. Until such time as the management system is fully operable, the nonregional concept is preferable.

As discussed in chapter VII, excessive chlorine residuals may be determental to the aquatic environment and, additionally, produce by-products toxic to man. During the defined dry weather conditions, flow in Clear Creek is effluent dominated. Therefore, it is important to produce an effluent with the minimum allowable chlorine residual. Consideration should be given to adding a maximum allowable chlorine residual as well as the presently permitted minimum values.

Conclusions and Recommendations

1) Based on the results of the segment analysis, continuation of the existing level of technology will not obtain the desired water quality in the stream segment.

2) The only methods available to meet the desired stream standards involve eliminating portions of the wasteload from the segment. This requires either land disposal techniques, which are not considered feasible in the area, or interfasin transport.

3) Based on the nutrient analysis presented in the Clear Lake section, it is questionable whether phosphorus controls for sewage treatment plants provide sufficient benefit to justify the additional cost. Therefore, consider the elimination of the phosphorus removal requirements based on a thorough study of the eutrophication potential, with and without point source controls.

4) Continue nonregional development in the basin unless detailed planning efforts dictate regional systems are preferable and a management program is available to implement the system.

5) Based on the results of the simulation model, wet weather pollution is projected to be a problem in Clear Creek. Dissolved oxygen concentrations drop to low levels within the 1983-1990 time frame. Fecal coliform concentrations become excessive between the present time and 1983.

6) Urban runoff constitutes the majority of the wet weather wasteloads.

7) Verification of the simulation models should be obtained prior to incurring the expense of implementating control strategies.

8) Evaluate interbasin transport of major municipal dischargers (at effluent Set 2) in order to assess economic advantages and the fishable/swimmable water quality criteria. If interbasin transport is determined not be be feasible, upgrade and operate existing and future treatment facilities at effluent set 4NA and drop dissolved oxygen standard to 4.5 mg/l.

9) Vegetative control techniques and small scale retention may be able to provide the desired BOD reductions with ease of implementation and low cost and maintenance. Since these control strategies require additional amounts of land, it is urgent that the model be verified and land be reserved in planned developments in an expedient manner. Otherwise, nonpoint source pollution may be extremely expensive to correct or become an irreversible problem.

10) The fecal coliform concentrations observed are very high and in need of particular attention during the verification steps. If fecal coliform are indeed found to exist in such huge concentrations, it may not be worth the expense to attempt to reduce the concentrations to "swimmable" standards.

11) "Good housekeeping" measures are one of the few controls that can be applied to existing developments without major commitments of resources. Although their effectiveness in providing the entire pollutant reduction is doubtful, these simple techniques may be able to contribute to wasteload reduction with very little economic and social disruption.

12) Maximum limits on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Clear Creek Tidal

Description of Area

Clear Creek tidal portion is the stream segment separating Clear Creek nontidal from Clear Lake. The tidal portion of Clear Creek begins at FM 528 and flows approximately 10 miles, forming the boundary between Harris County and Galveston County, prior to entering Clear Lake. The future population in the basin served by municipal treatment systems is projected at 38,200 by 1995.

Results of Dry Weather Segment Analysis

Water quality in the tidal portion of Clear Creek was simulated with the EPA simplified model as previously discussed. Assumptions utilized in the model are presented in Appendix A.

The tidal portion of Clear Creek is divided into three geographical planning areas. The location of each area and its relationship to the various regionalization concepts is indicated in Exhibits IV-2 through IV-4.

The water quality levels addressed for this stream segment are listed in Table IV-5 below.

TABLE IV-5

WATER QUALITY LEVELS
CLEAR CREEK - TIDAL

Level	D.O. (mg.1)	Fecal Coliform (MPN/100 ml)
I	As available from modified effluent set 3NP	As available from modified effluent set 3NP
II	4.0	< 2,000
III	5.0	< 200

The permitted effluent level for Clear Creek is referred to as a modified 3NP. The difference is that the suspended solids level for the Creek is permitted at 12 mg/l rather than 10 mg/l as defined by level 3NP.

Water quality for Clear Creek tidal is simulated based on the 1995 projected wasteloads and the existing level of permitted wastewater treatment. Three regionalization concepts are analyzed based on the geographical planning areas developed in the basin.

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration of at least 5.0 mg/l and a fecal coliform concentration of less than 200 MPN/100 ml.

Other conclusions developed in the segment analysis are:

1) Portions of the Clear Creek tidal segment require periodic maintenance dredging. During dredging operations, an additional wasteload of 1,800 pounds BOD/day is estimated to enter the segment, along with very high concentrations of suspended solids. This wasteload due to dredging is an increase of more than 1,000 percent of the daily carbonaceous BOD load from point source dischargers and results in a low water quality. However, dredging operations are not continuous in the area and are estimated to occur approximately every three years for a duration of three months. Therefore, no structural control is recommended.

2) For dry weather conditions, nonpoint source wasteloads (except dredging) are not significant.

3) Nutrient loadings from point sources discharging into Clear Creek are presently controlled and do not present a problem in the tidal portion. However, the nutrients contribute to the overall loading in Clear Lake which has a potential nutrient problem.

Analysis of Themes

Since the water quality projections for 1995 meet or exceed the fishable/swimmable criteria of water quality level III, except during dredging activities, and since further control of nutrients was rejected as a control theme (as presented in the Clear Lake section), Clear Creek tidal segment requires no further analysis. The only theme (Theme 1) to be evaluated is as follows:

Continue operation of existing plants at modified effluent set 3NP.

Construct future plants for operation at modified effluent set 3NP.

This theme is defined as the continuation of the existing level of technology.

Discussion of Themes Evaluated

By definition, continuation of the existing level of technology produces Water Quality Level I in the stream segment. However, in this case, the resulting water quality is better than the water quality criteria specified by levels II and III. The costs associated with this theme are indicative of the costs to provide sewage treatment to the existing and future projected population in the basin.

Table IV-6 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE IV-6

COMPARISON OF THEMES/CONCEPTS
CLEAR CREEK - TIDAL

Theme	Concept	Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional (A)	III	6	$12,400,000
1	Semi-regional (B)	III	3	12,800,000
1	Regional (C)	III	1	11,500,000

The stream segment profiles depicting D.O. concentrations for each of the themes/concepts described are presented in Appendix A, Figures IV-24 through IV-26.

Results of Wet Weather Segment Analysis

Although no stormwater simulation model has been developed specifically for Clear Creek Tidal, it is possible that wet weather water quality reflects that evidenced in the nontidal portions of Clear Creek due to similar land uses and growth patterns. Therefore, it is recommended that a monitoring program be implemented simultaneously with the model verification program described for Clear Creek Nontidal basin to determine wet weather water quality in the tidal portion of Clear Creek. If stormwater runoff is found to degrade water quality to undesirable levels, the sampling of wasteloads and the formation of test areas for control strategies similar to those presented for the nontidal portion of Clear Creek are suggested. Development policies requiring the allotment of land for runoff control techniques should be implemented immediately upon verification of a wet weather water quality problem.

Discussion

The tidal portion of Clear Creek is projected to meet the defined fishable/swimmable water quality throughout the planning period. This conclusion is based on the projections of a nonspecific water quality simulation model that is uncalibrated and unverified. The results, therefore, must be considered as a rough estimate in need of verification. Similarly, the portion of the technical subplan related to wet weather conditions needs some verification. If a water quality monitoring program does not adequately verify the models predictions, and further indicates that water quality problems exist, calibrated and verified simulation models will be required to fully assess the water quality of the segment.

Phosphorus is not one of the parameters that impacts on the water quality simulation model. The costs/benefits of phosphorus removal as presently required in the Clear Lake drainage basin is also in question. A discussion of phosphorus removal is contained in the Clear Lake section.

As discussed in the Clear Creek nontidal section, continuation of the nonregional treatment system is preferrable at this time and institution of maximum allowable chlorine residuals is recommended.

Conclusions and Recommendations

1) Based on the results of the segment analysis, continuation of the existing level of technology results in water quality that meets or exceeds the criteria for fishable/swimmable streams. Therefore, it is recommended that the technical subplan for Clear Creek tidal is to continue controlling pollution at the existing level of technology.

2) Since dredging activities impact greatly on the water quality, it is recommended that dredging operations be prohibited during critical low flow stream conditions.

3) Based on the nutrient analysis presented in the Clear Lake section, it is questionable whether phosphorus controls for sewage treatment plants provide sufficient benefit to justify the additional cost. Therefore, it is recommended that a study of the phosphate loadings and eutrophication potential in the Clear Creek/Clear Lake drainage area be instituted.

4) Monitor water quality during dry and wet weather to verify model predictions and assumptions.

5) Continue nonregional development unless detailed planning dictates regional systems.

6) Maximum limits on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Clear Lake

Description of Area

Clear Lake is located approximately 23 miles southeast of downtown Houston. The lake forms a portion of the border between Harris County and Galveston County and serves as a major contact recreational facility in the area. The future population served by municipal sewage treatment systems is projected at 59,900 by 1995.

Clear Lake is a tidal influenced segment discharging to Galveston Bay. Major tributaries include Clear Creek, Armand Bayou, and Taylor Lake.

Results of Dry Weather Segment Analysis

Water quality in Clear Lake is simulated utilizing the EPA simplified model. The drainage basin is being analyzed as a single geographical planning area. The location of the area is presented in Exhibit IV-2.

The water quality levels addressed for Clear Lake are listed in Table IV-7.

TABLE IV-7

WATER QUALITY LEVELS
CLEAR LAKE

Level	D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
I	As available from modified effluent set 3NP.	As available from modified effluent set 3NP
II	4.0	200
III	5.0	200

The permitted effluent level for Clear Lake is referred to as a modified 3NP. The difference is that the suspended solids level for the Lake is permitted at 12 mg/l rather than 10 mg/l as defined by level 3NP.

Water quality for Clear Lake is simulated based on the 1995 projected wasteloads and the existing level of permitted wastewater treatment. Three regionalization concepts are analyzed.

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration of at least 5.0 mg/l and a fecal coliform concentration of less than 200 MPN/100 ml.

Other conclusions developed in the segment analysis are:

1) The channel in Clear Lake proper has required no maintenance dredging in the past 20-25 years according to the Galveston office of the Corps of Engineers. Only small segments at the head of the lake near Clear Creek and in the channel leading to Galveston Bay have been dredged. Any maintenance dredging done in Clear Lake will depend upon the results of shoaling. When this occurs, the additional wasteload estimated will be 1,800 pounds of BOD and very high suspended solids concentrations. The wasteload from dredging is equivalent to an increase of more than 2,000 percent of the daily carbonaceous BOD wasteload from point sources discharging into Clear Lake and results in a low water quality. However, since dredging occurs so infrequently, no structural controls are recommended.

   When dredging occurs in deeper waters - such as lower Clear Creek Channel - dredge materials should be contained in such a manner as to prevent loss of water transparency. Upland disposal sites should not be located in wetlands.

2) For dry weather conditions, other nonpoint source wasteloads are not significant.

3) The nonpoint source report identifies approximately 60 tons per year of total phosphates entering the Clear Creek/Clear Lake drainage basins annually by 1995. Future point source wasteloads based upon the alternative technical subplans for the Creeks will contribute approximately 110 tons per year. The total annual load of phosphorus entering Clear Lake has the potential for creating eutrophication problems.

4) Although wasteloads from boats, organic and petroleum based have not been determined, the high level of boating activity in Clear Lake should not be overlooked. Considering this high boat density in Clear Lake, it is possible the cumulative impact from this source of waste could preclude the use of the Lake for such activities. Programs for the permitting and/or prevention of such discharges now exist and are administered by the U.S. Coast Guard (marine waters) and Texas Department of Water Resources (fresh waters).

Consideration should be given to the determination of the effects of boat discharges ad a wasteload source on Clear Lake (in particular) and in other areas.

Analysis of Themes

The water quality in Clear Lake is projected to meet or exceed Water Quality Level III, the fishable/swimmable goals, except during dredging activities. Therefore, only nutrient loadings remain as a potential problem and are considered in the development of themes.

The themes to be evaluated are as follows:

Theme	Description
1	Continue operation of existing plants discharging directly into Clear Lake at modified effluent set 3NP. Construct any future plants discharging directly into Clear Lake for operation at modified effluent set 3NP.
2	Continue operation of all existing plants in the greater Clear Lake drainage basin (i.e., any Plant discharging to Clear Creek, Clear Lake or Armand Bayou) at modified effluent set 3NP. Construct any future plants in the greater Clear Lake drainage basin for operation at modified effluent set 3NP.
3	Upgrade all existing plants in the greater Clear Lake drainage basin to effluent set 4NP. Construct any new plants in the greater Clear Lake drainage basin for operation at effluent set 4NP.
4	Reduce effluent requirements in the greater Clear Lake drainage basin by removing the phosphorus restriction.

Discussion of Themes Evaluated

Since the projected water quality in Clear Lake meets or exceeds the fishable/swimmable criteria for dissolved oxygen and fecal coliform, defined by level III, the themes evaluated deal only with nutrient concentrations.

Theme 1 is a continuation of the existing level of treatment for municipal plants discharging directly into Clear Lake. The cost associated with Theme 1 is indicative of the cost for providing the presently permitted level of sewage treatment services to the existing and future population in the Clear Lake geographical planning area without regard to improved water quality.

Themes 2, 3 and 4, are all concerned with the greater Clear Lake drainage basin (Clear Creek, Clear Lake, and Armand Bayou). Projected dissolved oxygen and fecal coliform concentrations meet or exceed the defined fishable/swimmable water quality criteria. The difference between these 2, 3, and 4, is the amount of total posphorus in the point source effluents.

Theme 2 is a continuation of the existing standard with total phosphorus limited at 2.0 mg/l in point source discharges. Theme 3 calls for a reduction in the total phosphorus to 1.0 mg/l. Theme 4 calls for elimination of the total phosphorus restriction which will increase the concentration in point source discharges to an estimated 10.0 mg/l.

Allowable nutrient loadings to prevent eutrophication have not been defined for Clear Lake. However, based on the previously defined loading for Lake Houston of 0.48 grams per square meter per year to Clear Lake to prevent eutrophication is used for comparison purposes.

As indicated in the segment analysis for Clear Lake, the total annual loadings of phosphorus from point sources and nonpoint sources are far in excess of 3 tons per year. Even at a fifty percent reduction of point source loads, as called for in Theme 3, the 3 ton per year figure is greatly exceeded.

The costs associated with Themes 2, 3, and 4, are a comparison of the costs associated with various levels of phosphorus control for all sewage treatment plants discharging into the greater Clear Lake drainage basin. Table IV-8 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE IV-8

COMPARISON OF THEMES/CONCEPTS
CLEAR LAKE

Theme	Concept	Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional (A)	III	4	$ 7,800,000
1	Semi-regional (B)	III	2	7,500,000
1	Regional	III	1	7,300,000
2	Semi-regional (B)	III		52,100,000
3	Semi-regional (B)	III		55,700,000
4	Semi-regional (B)	III		46,400,000

The stream segment profiles depicting D.O. concentrations for each of the concepts with the continuation of existing technology are presented in Appendix B, Figures IV-27 through IV-29.

Results of Wet Weather Segment Analysis

Although no stormwater simulation model has been developed specifically for Clear Lake, it is possible that wet weather water quality reflects that evidenced in the nontidal portion of Clear Creek due to similar land uses and growth patterns. Therefore, it is recommended that a monitoring program be implemented simultaneously with the model verification program described for Clear Creek Nontidal basin to determine wet weather water quality in Clear Lake. If stormwater runoff is found to degrade water quality to undesirable levels, sampling of wasteloads and the formation of test areas for control strategies similar to those presented for the nontidal portion of Clear Creek are suggested. Development policies requiring the allotment of land for runoff control techniques should be implemented immediately upon verification of a wet weather water quality problem.

Discussion

Clear Lake is projected to meet the defined fishable/swimmable water quality goals. The projected water quality is based on a nonspecific simulation model that is uncalibrated and unverified. Therefore, in order to fully justify the conclusions, a monitoring program should be initiated to verify the models predictions.

Consideration for eliminating the existing requirements for point source phosphorus controls in the entire Clear Lake drainage basin is being recommended because insufficient evidence exists concerning the benefits that this costly control will provide. The phosphorus contributions from nonpoint source runoff throughout the drainage basin and the contribution from Galveston Bay through tidal transfer have not been fully assessed. These phosphorus loadings have the potential to contribute a greater annual load to Clear Lake thatn that derived from point sources. Therefore, it is recommended that elimination of the point source phosphorus control requirements be considered by TDWR based on a thorough evaluation of the sources and effects of phosphorus entering Clear Lake.

Regionalization potential and chlorine residual limitations have been discussed in the Clear Creek nontidal section. The comments and considerations apply equally to the Clear Lake basin.

Conclusions and Recommendations

1) The selection of a control theme for Clear Lake must be based on more than the resulting dissolved oxygen and fecal coliform levels. All three themes meet or exceed the fishable/swimmable criteria for those parameters. Therefore, the recommended theme is selected based on nutrient considerations.

   Based on the existing information, it is questionable whether phosphorus control in sewage treatment plant effluent provides sufficient benefit to justify the additional cost. Therefore, it is recommended that a complete study of the eutrophication potential and sources of phosphorus contribution to Clear Lake be initiated.

2) Since dredging activities impact greatly on the water quality, it is recommended that dredging operations be prohibited during critical low flow stream conditions.

3) Continue nonregional development in the basin unless detailed planning efforts indicate that regional systems are preferred.

4) Monitor the water quality of Clear Lake in order to verify the predictions of the simulation model and the assumed wet weather conditions.

5) Maximum limits on chlorine residuals from wastewater treatment plants should be considered by the TDWR.

Armand Bayou

Description of Area

Armand Bayou is located approximately 10 miles southeast of downtown Houston. The bayou flows south to Clear Lake and is cominated by tidal influences. Armand Bayou is not presently a classified segment. The future population served by municipal treatment systems is projected to be 54,400 by 1995.

Results of Dry Weather Segment Analysis

Water Quality in Armand Bayou is simulated utilizing the EPA Simplified Model as previously discussed. Assumptions utilized in the model are presented in Appendix A.

The Armand Bayou drainage basin is divided into three geographical planning areas. The location of each planning area and their relationship to various alternative regionalization concepts is indicated in Exhibits IV-2 through IV-4.

The water quality levels addressed for this stream segment are listed in Table IV-9 below.

TABLE IV-9

WATER QUALITY LEVELS
ARMAND BAYOU

Level	D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
I	As available from modified effluent set 3NP.	As available from modifield effluent set 3NP.
II	2.0	2,000
III	5.0	200

The permitted effluent level for Armand Bayou is referred to as a modified 3NP. The difference is that the suspended solids level for the bayou is permitted at 12 mg/l rather than 10 mg/l as defined by level 3NP.

Water quality for Armand Bayou is simulated based on 1995 projected wasteloads and the existing level of permitted wastewater treatment. Three regionalization concepts are analyzed based on the geographical planning areas developed in the basin.

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration from 3.0 to 4.8 mg/l at the critical point, depending on the various regionalization concepts. Projected levels of fecal coliforms remain below 200 MPN/100 ml.

Conceptual results of the segment analysis are presented in Table IV-10 along with the initial evaluation of pollution control themes. Except where otherwise stated, it is assumed that the majority of the future population is served by centralized treatment systems as opposed to septic tank systems.

TABLE IV-10

ARMAND BAYOU SEGMENT ANALYSIS

Segment: unclassified, low flow

Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
		D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
All future wasteloads at effluent set 3NP.	Existing Technology	3.0-4.8	< 200
Reduce wasteload to stream	Increase level of effluent treatment, interbasin transport, land application	5.0	< 200

Additional conclusions developed in the segment analysis are:

1) For dry weather conditions, nonpoint source wasteloads are not significant.

2) Nutrient loading into Armand Bayou does not present a problem to the segment. However, the nutrients contribute to the overall load in Clear Lake, which has been identified as having a potential nutrient problem.

Analysis of Themes

Several wasteload control themes are available to meet the desired water quality as specified in the segment analysis. The themes analyzed and their rejection or acceptance for additional study is presented below:

Theme	Description
1	Continue operation of existing plants at modified effluent set 3NP. New population served by septic tank systems. This theme was rejected for further study because the future population cannot feasibly be served by septic tanks.
2	Continue operation of existing plants at modified effluent set 3NP. Construct new plants for operation at modified effluent set 3NP. This theme was accepted for further study.
3	Reduce effluent wasteload by upgrading treatment efficiency to level 4NP. This theme was accepted for further study.
4	Reduce effluent wasteload by utilizing land application techniques for major discharges. This theme was rejected because land disposal is not considered feasible in this portion of the study area.
5	Reduce effluent wasteload by utilizing interbasin transport of major dischargers. This theme was accepted for further study.

Discussion of Themes Evaluated

Theme 2 is a continuation of the existing permitted conditions for the stream segment. By definition, Theme 2 will produce Water Quality Level I in the stream segment. In Armand Bayou the projected dissolved oxygen concentration resulting from Theme 2 varies from 3.0 mg/1 to 4.8 mg/1, depending on the regionalization concept. Fecal coliform concentrations remain below 200 MPN/100 ml for all three concepts.

The water quality produced by continuing the existing permitted conditions exceeds the quality criteria defined by Water Quality Level II (see Table IV-9). The cost associated with theme 2 is indicative of the cost for providing sewage treatment services to the existing and future projected population in the basin without regard to the desired fishable/swimmable water quality criteria.

Theme 3 requires implementation of controls and strategies that will upgrade the level of sewage treatment to effluent set 4NP and result in improved water quality in Armand Bayou. Theme 3 was evaluated for the nonregional concept but is equally applicable to the semi-regional concept.

Application of theme 3 for the nonregional and semi-regional concepts produces a dissolved oxygen concentration between 4.0 and 4.5 mg/1 based on the simulation modeling technique. The resulting concentration is less than the criteria specified by Water Quality Level III.

Theme 5 is based on transporting effluent from major dischargers in geographical planning area AB-1 out of Armand Bayou to Galveston Bay via Pine gully in order to achieve the criteria specified by Water Quality Level III. Theme 5 was evaluated for the nonregional concept but is equally applicable to the semi-regional concept.

The costs associated with themes 3 and 5 include the cost to provide sewage treatment service to the projected population plus the cost to obtain improved water quality. Table IV-11 presents the themes/concepts evaluated and the estiamted present worth costs for implementation.

TABLE IV-II

COMPARISON OF THEMES/CONCEPTS
ARMAND BAYOU

Theme	Concept	Level Achieved	Municipal Dischargers Projected	Present Worth Cost
2	Nonregional (A)	I, II	4	$13,300,000
2	Semi-regional (B)	I, II	2	12,700,000
2	Regional (C)	III	1	12,700,000
3	Nonregional (A)	II*	4	14,400,000
5	Nonregional (A)	III	4	11,400,000

*This theme/concept very nearly achieves level III with projected D.O. between 4.0 and 4.5 mg/l.

The stream segment profiles depicting D.O. concentrations for the themes/concepts described are presented in Appendix B, Figures IV-30 through IV-34.

Results of Wet Weather Segment Analysis

Although no stormwater simulation model has been developed specifically for Armand Bayou, it is possible that wet weather water quality reflects that evidenced in the nontidal portion of Clear Creek due to similar land uses and growth patterns. Therefore, it is recommended that a monitoring program be implemented simultaneously with the model verification program described for Clear Creek Nontidal basin to determine wet weather water quality in Armand Bayou. If stormwater runoff is found to degrade water quality to undesirable levels, sampling of wasteloads and the formation of test areas for control strategies similar to those presented for the nontidal portion of Clear Creek are suggested. Development policies requiring the allotment of land for runoff control techniques should be implemented immediately upon verification of a wet weather water quality problem.

Discussion

The Armand Bayou water quality during critical dry weather conditions is projected to fall below the defined goal for fishable/swimmable water quality. The prediction is based on the results of water quality simulation utilizing a nonspecific model that is neither calibrated nor verified for Armand Bayou. Therefore, there is a need to verify the modeled conclusions as part of the implementation program or the continuing planning process.

Other considerations including elimination of phosphorus controls, continuation of nonregional development, and maximum chlorine residuals, have been discussed in the Clear Lake portion of this report. The same conclusions are valid for Armand Bayou.

Conclusions and Recommendations

1) Armand Bayou is an unclassified stream segment which is not projected to achieve the desired water quality if the existing level of permitted discharges are continued. These conclusions are based on the results of a nonspecific water quality simulation model.

2) The same model predicts that theme 3 achieves a dissolved oxygen concentration of approximately 4.5 mg/l and very nearly meets the desired fishable/swimmable water quality criteria.

3) Theme 5 is capable of meeting Water Quality Level III. However, the impacts of the additional wasteload discharged into Pine Gully and Galveston Bay have not been addressed.

4) Based on the above conclusions, it is recommended that theme 2 be adopted for the present. Further studies to determine the validity of the steady-state model should be implemented or a specific water quality model for Armand Bayou should be developed.

5) Armand Bayou should be classified as a stream segment with applicable water quality standards.

6) Wet weather water quality should be monitored during storm conditions to determine if fishable/swimmable goals are achievable.

7) If further verified modeling efforts indicate that defined water quality criteria can be achieved, selection of another alternative technical subplan may be appropriate. Until then, expenditures to increase the level of control of the existing standards is not recommended.

8) Based on the phosphorus analysis presented in the Clear Lake section, it is recommended that phosphorus controls be eliminated until a detailed study of the eutrophication potential of Clear Lake, with and without point source controls, proves a need.

9) Continue nonregional development in the basin unless detailed planning efforts indicate that regional systems are preferable.

10) Maximum limites on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Dickinson Bayou

Description of Area

Dickinson Bayou is located in the southeast portion of the planning area, approximately 25 miles from downtown Houston. The principal communities in the vicinity of the bayou are Friendswood and Dickinson. The future population to be served by municipal treatment systems is projected to be 31,000 by 1995.

Dickinson Bayou is classified into two segments - that portion above tidal influences and the portion affected by tides. The stream flows in an easterly direction for approximately 25 miles until entering Dickinson Bay and then Galveston Bay.

Results of Dry Weather Segment Analysis

Water quality in the nontidal portion of Dickinson Bayou is simulated through a comparison of total assimilative capacity versus total wasteload, for the tidal segment utilizing the EPA Simplified Model as previsously described. Assumptions and constants used in the model are presented in the Appendix. The basin is being analyzed as a single geographic planning area as shown in Exhibit IV-2.

The water quality levels addressed for Dickinson Bayou are listed in Table IV-12 below.

TABLE IV- 12

WATER QUALITY LEVELS
DICKINSON BAYOU

Segment	Level	D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
Tidal & Nontidal	I	As available from existing level of permitted treatment.	As available from existing level of permitted treatment.
Nontidal	II	5.0	< 2,000
Nontidal	III	5.0	< 200
Tidal	II	4.0	< 200
Tidal	III	5.0	< 200

Dickinson Bayou - Nontidal. Since there is only one municipal discharger in the nontidal portion of Dickinson Bayou, the segment is evaluated in a similar manner as presented in the TDWR Wasteload Evaluation Report. The calculated assimilative capacity (CAC) of the segment is based on factors contained in the Wasteload Evaluation Report. The segment target load (STL) is determined as follows:

STL = CAC - 0.1 CAC - uncontrollable nonpoint source wasteloads.

One tenth of the calculated assimilative capacity is deducted as a safety factor and uncontrollable nonpoint sources are assumed to be negligible.

Table IV-13 presents the segment target load for dissolved oxygen standards of 4.0 and 5.0 mg/l based on the calculated assimilative capacity.

TABLE IV-13

SEGMENT TARGET LOAD

D.O. (mg/l)	CAC (lbs/day)	STL (lbs/day)
4.0	123	111
5.0	87	78

The 1995 projected wasteload for the Friendswood #3 treatment plant operating at effluent set 1 is 99 pounds of oxygen demand per day.

Dickinson Bayou - Tidal. The initial water quality simulation for the tidal portion of Dickinson Bayou is based on the 1995 projected wasteloads and the existing level of permitted discharge. Three regionalization concepts are analyzed.

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration from 3.6 to 4.0 mg/l at the critical point, depending on the various regionalization concepts. Projected levels of fecal coliform remain below 200 MPN/100 ml.

Conceptual results of the segment analysis are presented in Table IV-14 along with the initial evaluation of pollution control themes. Except where otherwise stated, it is assumed that the majority of the future population is served by centralized treatment systems as opposed to septic tank systems.

TABLE IV-14

DICKINSON BAYOU TIDAL SEGMENT ANALYSIS

Segment: 1103, low flow

Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
		D.O. (mg/l)	Fecal Coliform (MPN/100ml)
All future wasteloads at effluent set 2 with phosphorus removal	Existing Technology	3.6-4.0	< 200
Reduce wasteload to stream	Increase level of treatment, inter-basin transport, land application	5.0	< 200

Additional conclusions developed in the segment analysis for both the tidal and nontidal portions are:

1) For dry weather conditions, nonpoint source wasteloads are not significant.

2) At the presently permitted level of treatment, nutrient loadings to the stream do not present a problem.

Analysis of Themes

Several wasteload control themes are available to meet the desired water quality as specified in the segment analysis. The themes analyzed and their rejection or acceptance for additional study is presented below for both the tidal and nontidal segments.

Theme	Description
1	Continue operation of existing plants at their present effluent limits. New population served by septic tank systems. This theme was rejected for further study because the future population cannot feasibly be served by septic tanks.
2	Continue operation of existing plants at their present effluent limits (effluent set 1 in the nontidal portion and effluent set 2P in the tidal section). Construct new plants for operation at effluent sets 1 and 2P in the nontidal and tidal segments respectively. This theme was accepted for further study as the continuation of existing technology.
3	Reduce effluent wasteload by upgrading the level of treatment. This theme was accepted for further study.
4	Reduce effluent wasteload by utilizing land application techniques for major discharges. This theme was rejected because land disposal is not considered feasible in this portion of the study area.
5	Reduce effluent wasteload by utilizing interbasin transport of major dischargers. This theme was rejected since water quality within the Clear Creek watershed does not allow for additional wasteloads. Other watersheds are either too distant or outside the planning area.

Discussions of Themes Evaluated

Dickinson Bayou - Nontidal. Theme 2 is a continuation of the existing level of technology for the stream segment. By definition, Theme 2 produces water quality Level I in the stream segment (D.O. = 4.5 mg/l and fecal coliform < 200 MPN/100 ml). The water quality produced by continuing the existing permitted conditions, exceeds the quality criteria defined by Water Quality Level II (see Table IV-12). The cost associated with Theme 2 is indicative of the cost for providing sewage treatment services to the existing and future projected population in the basin without regard to the desired fishable/swimmable water quality criteria.

Theme 3 requires upgrading the level of treatment from effluent set 1 to effluent set 2. The improved effluent quality will produce a dissolved oxygen concentration in Dickinson Bayou Nontidal above 5.0 mg/l based on the results of the segment analysis. The costs associated with Theme 3 include the cost to provide sewage treatment services to the projected population plus the cost to obtain improved (fishable/swimmable) water quality.

Table IV-15 presents the themes/concepts evaluated for Dickinson Bayou Nontidal portion and the estimated present worth costs for implementation.

TABLE IV-15

COMPARISON OF THEMES/CONCEPTS
DICKINSON BAYOU - NONTIDAL

Theme	Concept	Level Achieved	Municipal Dischargers Projected	Present Worth Cost
2	Nonregional (A)	I, II	1	$600,000
3	Nonregional (A)	III	1	700,000

Dickinson Bayou - Tidal. By definition, Theme 2 will produce Water Quality Level I in the segment. In Dickinson Bayou the projected dissolved oxygen concentration resulting from Theme 2 varies from 3.6 mg/l for the nonregional concept to 4.0 mg/l for the regional concept. The cost associated with Theme 2 is indicative of the cost for providing sewage treatment services to the existing and future population in the segment without regard to the desired fishable/swimmable water quality criteria.

Theme 3 for the tidal section requires upgrading the level of treatment from the existing effluent set 2P to effluent set 3NP for the nonregional concept and effluent set 2NP for the regional and semi-regional concepts. Theme 3 will improve effluent quality and result in improved water quality in Dickinson Bayou. The projected water quality from Theme 3, based on the segment analysis, meets or exceeds that defined by Water Quality Level III, the fishable/swimmable standard. The costs associated with Theme 3 include the cost to provide sewage treatment services to the projected population plus the cost to obtain improved water quality.

Table IV-16 presents the themes/concepts evaluated for Dickinson Bayou Tidal portion and the estimated present worth costs for implementation.

TABLE IV-16

COMPARISON OF THEMES/CONCEPTS
DICKINSON BAYOU - TIDAL

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
2	Nonregional (A)	I	3	$5,500,000
2	Semi-regional (B)	I, II	2	7,400,000
2	Regional (C)	I, II	1	6,400,000
3	Nonregional (A)	II, III	3	7,800,000
3	Semi-regional (B)	III	2	8,300,000
3	Regional (C)	III	1	8,200,000

The stream segment profiles depicting D.O. concentrations for the themes/concepts described are presented in Appendix B, Figures IV-35 through IV-40.

Results of Wet Weather Segment Analysis

Although no stormwater simulation model has been developed specifically for Dickinson Bayou, it is possible that wet weather quality in the two segments of the bayou reflect that evidenced in the nontidal portion of Clear Creek due to the similar land uses and growth patterns. Several studies have been done that show elevated fecal coliform levels resulting from storm runoff. This information is summarized in Report No. WQS-24 and is available from the Texas Department of Water Resources. Therefore, it is recommended that a monitoring program be implemented simultaneously with the model verification program described for Clear Creek Nontidal basin to determine wet weather water quality in Dickinson Bayou. If stormwater runoff is found to degrade water quality to undesirable levels, sampling of wasteloads and the formation of test areas for control strategies similar to those rpesented for the nontidal portion of Clear Creek are suggested. Development policies requiring the allotment of land for runoff control techniques should be implemented immediately upon verification of a wet weather water quality problem.

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16. Abstracts

The primary objectives of this Activity are to develop, evaluate, and recommend alternative technical methods for achieving water quality criteria during critical dry and wet weather stream conditions. Each subplan is evaluated for its major impacts including cost, energy utilization, land utilization, and environmental effects. Additionally, its reliability and sensitivity are evaluated.

Technical review and public participation are incorporated into the evaluation and selection of the preferred alternative technical subplan and its impacts. This process forms the basis for final plan selection.

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Discussion

The tidal and nontidal portions of Dickinson Bayou are projected to have water quality below that of the defined fishable/swimmable goals if the existing level of permitted discharges continues. The conclusion for the nontidal segment is based on a desk-top analysis of the Bayou's assimilative capacity and the projected wasteloads. The tidal portion of Dickinson Bayou was evaluated with a nonspecific water quality simulation model. Therefore, both analyses are based on uncalibrated and unverified input data which should be verified prior to implementing further control requirements.

Dickinson Bayou is divided into two classified segments by the State, each with defined water quality goals. Therefore, verification of the modeled results should be performed or a specific verified model for the entire Dickinson Bayou drainage basin should be developed as part of the implementation or continuing planning process in order to accurately set water quality criteria and effluent standards.

Of particular importance to the verification effort should be the following:

1) The level, reaction rate, and effect of ammonia-nitrogen in treatment plant effluent and in the Bayou.

2) The water quality during wet weather conditions in order to determine if storm water modeling is required.

The cost/benefit of point source phosphorus control as presently required in the tidal portion of the Bayou is not well known. The nonpoint source contributions of phosphorus from stormwater runoff and tidal dispersion are also not well defined. Therefore, it is recommended that phosphorus controls be eliminated until a detailed analysis indicates the need and benefits of point source phosphorus controls.

Other items discussed in the Clear Lake section include chlorine residuals and nonregional development. The same conclusions are valid for Dickinson Bayou.

Conclusions and Recommendations

1) Based on the segment analysis, continuation of the existing level of permitted discharge will not result in the desired level of water quality during dry weather conditions.

2) For the nontidal segment, upgrading from effluent Set 1 to effluent Set 2 will result in fishable/swimmable water quality.

3) For the tidal segment, upgrading to effluent Set 3N is projected to achieve the fishable/swimmable goal.

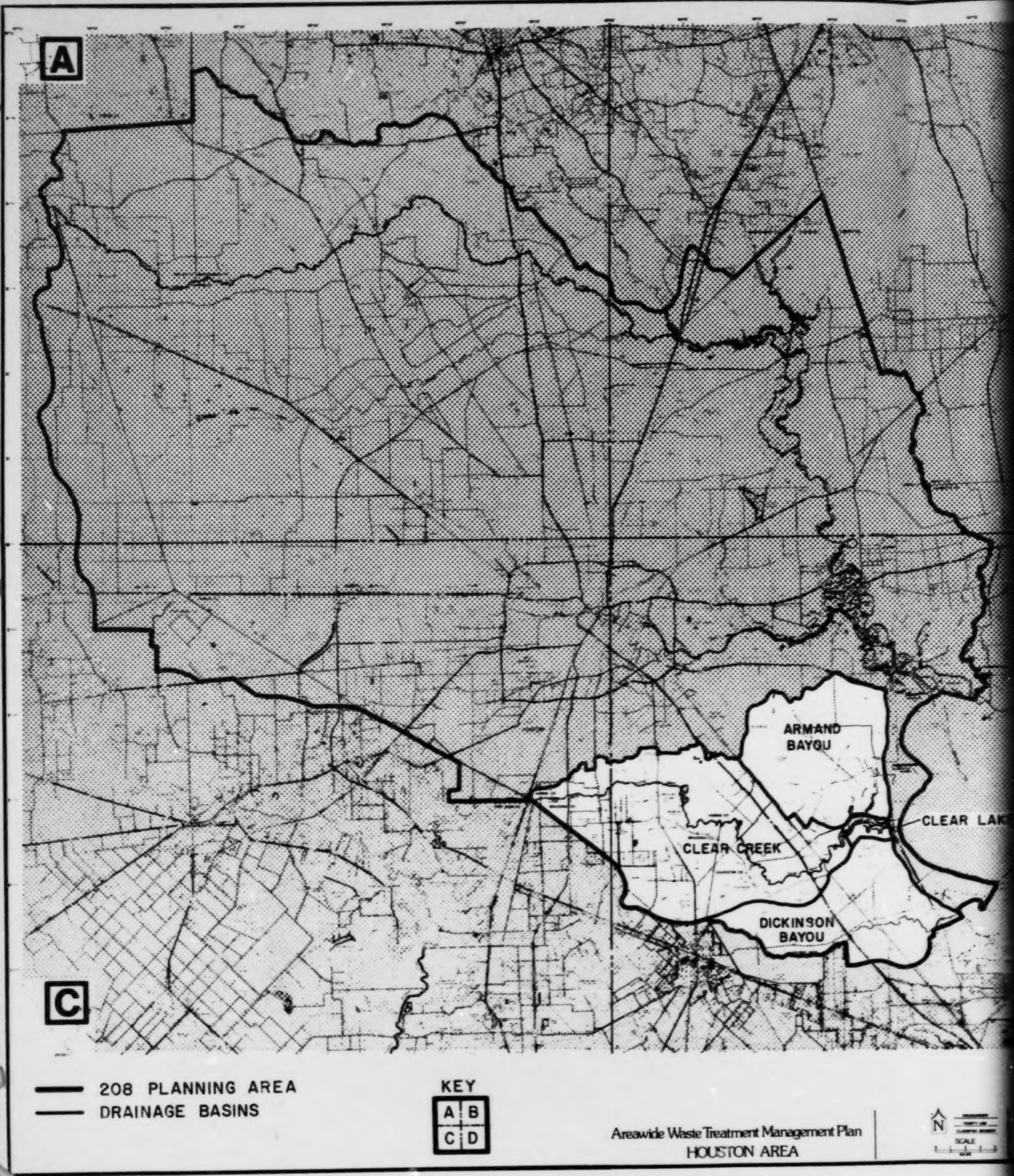
4) Verification of the dry weather modeling effort is recommended prior to implementation of control strategies. If results are extremely sensitive to ammonia-nitrogen wasteloads, consider setting a standard where restrictions do not presently exist.

5) Wet weather water quality monitoring is recommended to assess the need for further modeling and to evaluate the ability to achieve and maintain the fishable/swimmable goals.

6) There is insufficient information to support the advantages of phosphorus control and therefore, point source phosphorus controls should be eliminated until a detailed evaluation proves a need for reinstituting the control.

7) Maximum limits on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

8) Continue nonregional development in the basin unless detailed planning efforts indicate that regional systems are preferrable.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Areawide Waste Treatment Management Plan
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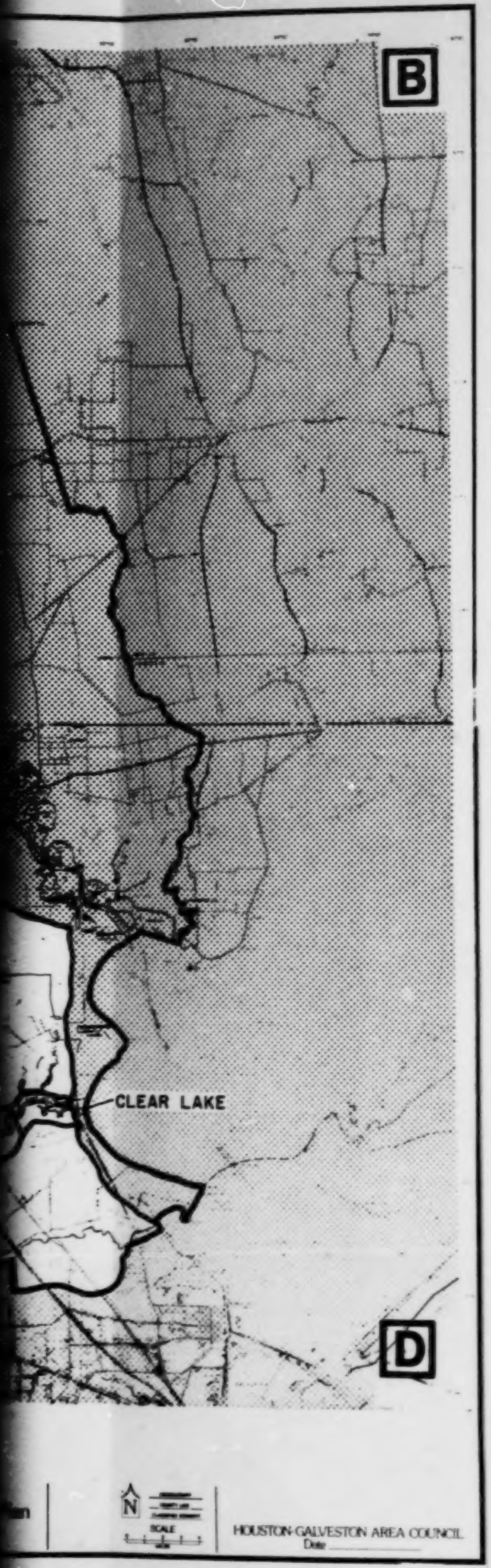
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GREATER HOUSTON 208 PROGRAM
HOUSTON-GALVESTON AREA COUNCIL

CLEAR CREEK/CLEAR LAKE
TECHNICAL SUBPLANNING AREA

DRAWN BY: ROY F. WESTON DATE:	REVISIONS BY: DATE:	EXHIBIT IV-1 SCALE SECTION

CHAPTER V - UPPER HOUSTON SHIP CHANNEL AND TRIBUTARIES TO CONFLUENCE WITH THE SAN JACINTO RIVER

CHAPTER V - UPPER HOUSTON SHIP CHANNEL AND TRIBUTARIES TO CONFLUENCE WITH THE SAN JACINTO RIVER

Introduction

The technical subplan area for the Houston Ship Channel and tributaries to the San Jacinto River is located in the central portion of the 208 planning area, Exhibit V-1. The major waterway within this area is the Houston Ship Channel, a major navigation artery which links the Port of Houston with Galveston Bay. The waterway receives and transports large quantities of waste from the Houston area urban-industrial complex.

In addition to the above sources, wastes are conveyed into the system via numerous tributaries. Significant contributions originate from municipal and industrial plants along Buffalo Bayou, White Oak Bayou, Brays Bayou, Sims Bayou, Hunting Bayou, Vince Bayou, Greens/Hall Bayou, and Carpenter Bayou. For ease of discussion, development of the alternative technical subplans is addressed separately for the Upper Houston Ship Channel and Turning Basin, Buffalo Bayou, and the remaining tributaries.

Houston Ship Channel

Description of Area

Within the confines of the technical subplanning area, the Houston Ship Channel extends from the Turning Basin, approximately 4 miles due east of downtown Houston, to the confluence with the San Jacinto River, approximately 16 miles downstream and east of the Turning Basin. Tidal action dominates the instantaneous hydrodynamic state of the waterway. Dispersive processes, induced principally by tidal oscillations, distribute applied wasteloads throughout the system. Net advective transport in the Channel is generally in an easterly direction with discharge to Galveston Bay.

Land use patterns in the area are urban-residential and industrial, with the latter situated primarily adjacent to the Ship Channel.

Results of Dry Weather Segment Analysis

The Houston Ship Channel Water Quality Simulation Model, calibrated and verified by the TDWR, is utilized for the dry weather segment analysis. Model output consists of BOD and D.O. deficit profiles. Nitrogenous and carbonaceous BOD levels are treated independently. The model, as discussed in the methodology section, includes the Houston Ship Channel from the upper reaches of Buffalo Bayou to Morgan's Point. A discussion of results for the segment from the confluence with the San Jacinto River to Morgan's Point is reserved for Chapter VI.

The basin is divided into 5 geographical planning areas by the methods discussed previously. The location of each area and the manner in which they are combined for the concepts of regionalization and semi-regionalization are indicated on Exhibit V-2 through V-4.

The main stream of the Upper Houston Ship Channel and the Turning Basin are assigned separate classifications by the TDWR. Segment 1006 constitutes the Houston Ship Channel from the Turning Basin to the confluence with the San Jacinto River. Segment 1007 is the Turning Basin. The water quality levels, addressed for this subplanning area, are presented with respect to segment in Table V-1.

TABLE V-1

WATER QUALITY LEVELS
UPPER HOUSTON SHIP CHANNEL AND TURNING BASIN

Level	Segment No.	D.O. (mg/l)	Fecal Coliform MPN/100 ml
I	1006/1007	As available from existing permitted effluent sets.	As available from existing permitted effluent sets.
IIa	1006	2.0	< 2000
IIa	1007	1.5	< 2000
IIb	1006/1007	3.0	< 2000
III	1006/1007	5.0	< 200

Water quality for the Houston Ship Channel is projected with steady state modeling techniques. Input data are based on 1995 projected industrial wasteloads and existing permitted levels of wastewater treatment for municipal discharges. Industrial point source discharges are identified and grouped on the basis of industrial category and subbasin. Each group is assigned an approximate discharge location along the Houston Ship Channel. Wasteload input to the Houston Ship Channel Water Quality Simulation Model is limited by model structure to one of 14 nodes. Municipal and industrial point sources are relocated to the nearest waste input node.

The total projected industrial wasteload, as presented in the Point Source Analysis, for 1995 is 21,000 pounds per day as carbonaceous BOD. Data presented in the Waste Load Evaluation for the Houston Ship Channel indicate that the 1977 recommended permit discharge is approximately 22,000 pounds per day of carbonaceous BOD and 8,000 pounds per day of ammonia-nitrogen. It was assumed that the 1995 industrial projections only accounted for carbonaceous BOD and therefore, the industrial ammonia-nitrogen wasteloads from the allocation report is added to those projections. Major ammonia-nitrogen point source dischargers are identified from data listed in the wasteload allocation report. Each discharge is associated with an industrial group and input to the model at a location consistent with the corresponding carbonaceous BOD discharge. The net ammonia-nitrogen loads from major dischargers is deducted from the total ammonia-nitrogen allocated and the remainder is distributed proportionally among the remaining industrial dischargers based on their carbonaceous BOD allocation.

In the discussion that follows, three regionalization concepts are analyzed based on the conceptualized geographical planning areas developed for the basin.

Results of the initial dry weather segment analysis indicate that future water quality of the Turning Basin and the Houston Ship Channel does not meet Water Quality Level III criteria. Based on model output, the projected dissolved oxygen concentration at the Turning Basin is 4.0 mg/l and improves continuously to 5.3 mg/l at the confluence with the San Jacinto River. However, model predictions show dissolved oxygen concentration does not exceed 5.0 mg/l for 13 statute miles downstream of the Turning Basin.

Water quality in bayous tributary to the Upper Houston Ship Channel is simulated by the SAC-III model (Chapter II). Based on model results from these simulations, the waste material, input to the Houston Ship Channel Model via Buffalo Bayou and Sims Bayou tributary flow, is approximately 30 percent of the total wasteload to segments 1006 and 1007 and constitutes the major portion of the wasteload to the reaches of the Ship Channel where projected dissolved oxygen is less than 5.0 mg/l. The heavy waste input through these two bayous is the probable reason for the consistency in dissolved oxygen level with respect to regionalization concept.

Output from tributary modeling with SAC-III is used as direct wasteload input to the Houston Ship Channel Water Quality Simulation Model. A complication that arises in this procedure is that the physical processes simulated by the above model are different. Tidal dispersion, a dominant factor in the upstream transport of dissolved oxygen, effectively inhibits modeling tributary water quality independent of Ship Channel water quality. The net effect of the dual modeling approach is discrepancies in the tributary D.O. and BOD profiles, predicted by the two models.

The D.O. concentration at the Turning Basin, predicted by the two models, differs by 1.5 mg/l with the Buffalo Bayou simulation model predicting a concentration of 5.5 mg/l and the Ship Channel model predicting a concentration of 4.0 mg/l. Part of the difference can possibly be attributed to the benthic loads used in the respective models. Since the tributary bayous (Buffalo and Sims) and their respective wasteloads play such a major role in the simulation of the Houston Ship Channel water quality, these bayous should be incorporated into the actual Houston Ship Channel Model.

For each concept, a "baseline" simulation is performed to determine the effects of channel conditions, stream hydraulics, and background benthic loads.(See Appendix B, Figure V-1). In each case, benthic demand predicted by the model accounts for approximately 40 percent of the total D.O. deficit at the Turning Basin. Benthic values, supplied by the TDWR and listed in Table V-2, include a 50 percent reduction in measured levels to account for improved treatment efficiencies. The model predicts a 4.5 mg/l D.O. at the Turning Basin if benthic demands are reduced to average background values for sandy bottom streams (Table V-2). Water Quality Level III criteria is still not achieved even with the reduced benthic loads.

Additional conclusions developed in the segment analysis are:

1) Fecal coliform levels are projected to remain below 200 MPN/100 ml.

2) For dry weather conditions, nonpoint source wasteloads are not significant.

Analysis of Themes

Based on the results of the segment analysis, water quality in the upper reaches of the Houston Ship Channel is dominated by Buffalo Bayou, Sims Bayou, and the defined benthic demand. Therefore, in

TABLE V-2

BENTHIC LOAD

River Segment (statute miles above Morgan's Point)	gm/m^2/day	
	Projected Benthic 1971 Verification Run (29.44°C)[1]	Benthic[2] (29.44°C)
22.8 to 24.7	1.65	0.91
20.7 to 22.8	2.07	0.91
19.5 to 20.7	2.28	0.91
17.8 to 19.5	1.96	0.91
15.5 to 17.8	1.55	0.91
13.3 to 15.5	1.41	0.91
11.8 to 13.3	1.36	0.91
0 to 11.8	1.31	0.91

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[1] Values are based on 50 percent of measured values corrected for temperature ($K_{ben} = K_{ben_{20}}(1.065)^{T-20}$).

[2] Based on average background value for sandy bottom streams, as supplied by the TDWR.

order to improve the water quality in the upper reaches of the Houston Ship Channel, wasteload reductions in the tributary bayous or supplemental oxygen input to the Ship Channel are required.

The themes analyzed for the Houston Ship Channel are as follows:

Theme	Description
1	Operate existing plants and future facilities at existing levels.
2	Reduce wasteload entering from tributary bayous.
3	Maintain treatment plants operation at existing permitted levels and apply instream aeration at sufficient points to achieve Water Quality Level III.

Discussion of Theme Evaluated

Theme 1 is a continuation of the existing level of permitted effluent discharge. Theme 1 achieves Water Quality Level II but falls short of meeting Level III fishable/swimmable goals. The costs associated with this theme are indicative of the costs to provide sewage treatment to the existing and future projected population in the basin. Figure V-1 shows the D.O. profile for Theme 1.

Theme 2 requires a reduction in the wasteload contribution from the bayous, tributary to the upper reaches of the Houston Ship Channel. Based on the Buffalo Bayou and Sims Bayou segment analyses, the Northside/69th Street complex and the Sims Bayou Treatment Plant contribute approximately 90 percent and 75 percent respectively of the total wasteload entering the upper reaches of the Houston Ship Channel from Buffalo and Sims Bayous. Therefore, Theme 2 calls for upgrading the level of sewage treatment at these two plants to effluent set 4N.

Based on the upgraded levels of treatment at Northside/69th Street and the Sims Bayou plant, the models predict 4.5 mg/l D.O. at the Turning Basin. The models further indicate that upgrading the remaining plants along Sims Bayou and Buffalo Bayou to effluent set 4N will still not achieve the desired water quality. Even if benthic demand is reduced to background levels for sandy bottom streams, the models predict a dissolved oxygen concentration of approximately 4.7 mg/l. Figure V-2 depicts the D.O. profile for the nonregional concept, Theme 2.

Theme 3 effects water quality improvement by supplying oxygen where natural sources of oxygen supply are not adequate to satisfy existing demands and still meet fishable/swimmable criteria. Instream aeration is exercised at the Turning Basin and in the vicinity of Brays Bayou since this reach of the Ship Channel experiences lowest D.O. levels.

Based on data currently available, the model predicts that Water Quality Level III is achieved if approximately 10,000 pounds per day D.O. is input at the Turning Basin and 8,000 pounds per day D.O. is input in the vicinity of Brays Bayou. The D.O. profile drops from 5.4 mg/l at the Turning Basin to 5.0 mg/l in the vicinity of Sims Bayou. Thereafter, a continuous improvement to 7.0 mg/l at Morgan's Point is predicted. Figure V-3 depicts the computed D.O. profile for the nonregional concept with instream aeration. It is anticipated that the D.O. profiles for the other two concepts are similar.

Table V-3 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE V-3

COMPARISON OF THEMES/CONCEPTS
HOUSTON SHIP CHANNEL

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional	II	11	$18,800,000
2	Nonregional	II	11	35,800,000
3	Nonregional	III	11	21,300,000

Results of Wet Weather Segment Analysis

The WRECEV water quality simulation model is utilized for the wet weather segment analysis, as discussed in Chapter II. The model includes the entire length of the Houston Ship Channel from five miles upstream of the Turning Basin on Buffalo Bayou to Galveston Bay. The San Jacinto River below the Lake Houston Dam to its confluence with the Ship Channel is also included in this model. The results for this segment are discussed in Chapter VI.

The simulation is applied over a twenty day period with the storm occurring in the first hour of the eighth day. Wasteloads and stormwater flows for 1975, 1983, 1990, and 1995 conditions are input to the model at predefined time intervals in specified junctions, as developed in the Nonpoint Source Analysis Report. The model then simulates the resulting stream flow and water quality versus time.

Currently, no standards exist specifically for wet weather situations. Therefore, the initial evaluation of resultant water quality is based upon dry weather standards.

Severe drops in dissolved oxygen concentrations are evidenced throughout the Ship Channel in 1995, as shown in Figures V-4 through V-11, in Appendix B. The junctions between Sims Bayou and the San Jacinto Bay contain less than 1.0 mg/l D.O. within one day after the storm. The remaining portions of this segment generally contain less than 2.0 mg/l D.O. The stream recovers very slowly with several junctions still below 1.0 mg/l within ten days following the storm. Due to tidal influences, the last junctions to recover are those in the central portion of the Ship Channel. As runoff wasteloads move down the stream, the upstream junctions increase in dissolved oxygen content. At the same time, the tides carry water in from Galveston Bay that dilutes the wasteloads and replenishes the dissolved oxygen content in the downstream junctions.

Fecal coliform concentrations do not exceed dry weather standards. The peak concentration evidenced is approximately 300 MPN/100 ml, with all concentrations below 200 MPN/100 ml within two days after the storm.

The simulations for the intervening years indicate poor water quality under present conditions that gradually worsens throughout the planning period. The 1975 stormwater runoff wasteloads also produce extremely low dissolved oxygen levels. The problem, however, is slightly less widespread than that evidenced in 1995. The area between Hunting Bayou and Burnett Bay contains less than 1.0 mg/l, with the remaining junctions generally below 3.0 mg/l. Several junctions remain below 1.0 mg/l for up to eight days following the storm.

The 1983 and 1990 conditions indicate a further deterioration in water quality from that observed in 1975. Each year more junctions falling below 1.0 mg/l are gradually included.

Analysis of Themes

Based on the results of the segment analysis, wet weather water quality in the Houston Ship Channel is presently extremely poor and gradually worsens throughout the planning period. To determine the need for runoff controls, the water quality necessary to preserve the water uses of the stream must be defined. Environmental information indicates that streams can be maintained as a fish and wildlife habitat with dissolved oxygen concentrations as low as 4.0 mg/l for short periods of time. Although this level of oxygen may hinder reproduction in some species, the fishlife can survive. However, dissolved oxygen concentrations of 3.0 mg/l or less may be detrimental to critical game fish in the stream. Based upon these criteria, runoff controls are investigated in order to bring D.O. levels to 4.0 mg/l.

Two general methods for wasteload reductions are considered. The first involves a percent reduction in all stormwater BOD wasteloads. With a fifty percent reduction, the model predicts that dissolved oxygen drops to 2.0-3.0 mg/l in most junctions. A seventy-five percent reduction results in D.O. concentrations of 4.0 mg/l or greater. As previously observed, the middle portions of the Houston Ship Channel (Carpenter's Bayou area) experience the lower concentrations. The majority of the segment contains over 5.0 mg/l with a seventy-five percent reduction in all BOD wasteloads.

The second method of stormwater wasteload reduction considered involves holding the "first flush" concentrations. Two water quality simulations were made, one retaining the first hour of runoff and the other retaining the first two hours. Modeling efforts indicate that the removal of the initial runoff loads has virtually no effect on the wet weather water quality of the Ship Channel. Due to the magnitude of stormwater wasteloads that enter this stream segment throughout the days following the storm, removal of the first few hours of runoff still results in dissolved oxygen concentrations of less than 1.0 mg/l.

Based on this analysis, the only reduction method that achieves a wet weather water quality that maintains the Houston Ship Channel as a fish and wildlife habitat is a seventy-five percent reduction in all stormwater runoff related BOD wasteloads.

Once the amount of necessary reductions is defined, the source of contributing wasteloads must be determined in order for control techniques to be identified. The summary of nonpoint source loads in the Nonpoint Source Analysis Report indicates that ninety percent of the BOD loadings from stormwater runoff in 1995 are attributable to urban land uses, The report also indicated that the increased BOD loading from 1975 to 1995 is accounted for by an increase in urban runoff wasteloads.

Since several categories of land uses are included under the general heading of "urban", an attempt was made to identify the loads from each category, with particular attention towards residential and industrial loads. However, the methodology for developing urban runoff wasteloads as presented in the Nonpoint Source Analysis Report does not allow for the separation of wasteloads from categories within a general type of land use. It is known that increasing industrialization and residential growth both increase impervious areas and, therefore, increase runoff wasteloads. Thus, proposed control techniques apply to both industrial and residential runoff.

Discussion of Themes Evaluated

Wet weather water quality in the Houston Ship Channel has been identified as an existing problem that results from urban runoff. It has also been determined that a seventy-five percent reduction in BOD runoff loads is necessary to preserve the desired water uses of the segment. Possible types of control techniques are evaluated below.

As previously discussed in Chapter IV on Clear Creek, vegetative control techniques can provide the necessary reduction in BOD loads. However, this method of runoff control requires large amounts of land which is not available within the City of Houston. This technique also cannot be implemented in existing developments. Therefore, vegetative controls are not applicable to the wet weather water quality problem of the Ship Channel.

Nonstructural controls such as performance or proscriptive standards directed at the Houston Ship Channel's industrial development are also inappropriate. The amount of runoff loads attributable to industries has not been identified, and therefore, necessary reductions and subsequent control strategies specific to industries cannot be determined.

Based on information provided in the Nonpoint Source Analysis Report, the only remaining control technique that will provide a seventy-five percent reduction in BOD wasteloads for an existing water quality problem is stormwater treatment. The quantity of stormwater runoff to be treated from the tributaries and inflow above the confluence with the San Jacinto River is over twenty billion gallons on the day of the storm.

The Nonpoint Source Analysis Report ranks physical/chemical treatment higher than biological treatment. The stormwater flow is assumed to be distributed among the tributary basins in 70-100 MGD treatment plants. Two types of physical/chemical treatment are roughly evaluated for capital costs. According to the cost curves in the Nonpoint Source Analysis Report, chemical clarification by single-stage lime addition would cost over $1 billion. Screening with microstrainers, which provide only a fifty percent BOD reduction, would cost over $350 million. These costs do not include operation and maintenance costs which would substantially add to the expenditure for stormwater treatment.

As can be seen from these estimations, stormwater treatment requires a large financial input. If the cost of maintaining the Ship Channel as a fishable segment during wet weather conditions is found to be excessive and undesirable, a re-evaluation of dry weather standards should be made. Dry weather control themes are designed to preserve the Houston Ship Channel for fishable/swimmable water uses. The Ship Channel should not be maintained as a fish and wildlife habitat in dry weather if it is not preserved as a fishable segment in wet weather.

Prior to incurring stormwater treatment expenses or taking action to redefine water uses for the segment, the magnitude of the wet weather quality problem should be verified. The extent of low dissolved oxygen concentrations can be determined by an instream monitoring program. Should water quality during wet weather be found to be as poor as the model predicts, control strategies should be implemented or dry weather standards re-evaluated consistent with wet weather conditions.

If preliminary monitoring indicates a water quality problem less severe than predicted and within a range that makes fishable/swimmable conditions more obtainable, the simulation model and loadings should be verified. Based upon verification of the simulation techniques, appropriate control strategies should be implemented.

The instream wet weather water quality monitoring program is a step in the evaluation of the Houston Ship Channel that requires immediate attention. Until the relative magnitude of a wet weather problem and its impact on the water uses of the segment are determined, dry weather control themes preserving the stream for fishable/swimmable conditions should not be implemented.

Discussion

Segments 1006 and 1007 of the Houston Ship Channel are projected to maintain a water quality below the defined fishable/swimmable criteria during dry weather, based on the results of the calibrated and verified steady-state simulation model. These segments are further projected to have a severe water quality problem during wet weather conditions based on an unverified nonsteady-state water quality simulation model.

Through the use of supplemental instream aeration, the dry weather fishable/swimmable water quality can be achieved. However, if the Ship Channel reacts to storm water runoff as indicated, there is no point in attempting to meet the defined fishable/swimmable dry weather standards.

A wet weather monitoring program should be initiated to verify the storm water model inputs and predictions, since existing observations do not support the models conclusions. If fishable/swimmable water quality can be maintained during wet weather, then supplemental instream aeration may prove beneficial. Until then it is recommended to continue the level of permitted discharges that presently exist for the basin.

The steady-state model should be further verified with emphasis on the nitrogenous and benthal oxygen demands. The model should also be expanded to include the tidal portions of the tributary bayous that contribute major wasteloads to the Houston Ship Channel.

Conclusions and Recommendations

1) Based on existing technology, the results of the segment analysis indicate that the projected water quality in the Upper Houston Ship Channel (Segment 1006) and the Turning Basin (Segment 1007) do not meet Water Quality Level III criteria.

2) Model results show that upgrading the Northside/69th Street complex and the Sims Bayou Plant to effluent set 4N does not improve water quality at the Turning Basin sufficiently to meet Water Quality Level III criteria. Upgrading other municipal plants along Buffalo Bayou and Sims Bayou to effluent set 4N is not a practical alternative for increasing D.O. at the Turning Basin since the smaller plants contribute a minor percentage of the waste conveyed into the Houston Ship Channel.

3) Enactment of Theme 3 requires instream aeration to increase the supply of dissolved oxygen to critical reaches of the Houston Ship Channel. Based on D.O. inputs of approximately 10,000 pounds per day at the Turning Basin and 8,000 pounds per day at Brays Bayou, the model predicts a shift in the D.O. sag from the Turning Basin to Sims Bayou. The model further predicts a minimum D.O. level of 5.0 mg/l near Sims Bayou, thus achieving Water Quality Level III.

4) Current estimated oxygen demand, created by dredging of sandy bottom channels, is 8,600 pounds per day. This figure is equivalent to approximately 60 percent of the BOD load entering the Ship Channel via Buffalo Bayou. Based on the predicted magnitude of the D.O. deficit at the Turning Basin and along the upper portion of Segment 1006, scheduled dredging activities should not be performed during critical flow periods.

5) The Houston Ship Channel Water Quality Simulation Model in its present form does not allow for modeling point source discharges along its tributaries. Since major wasteloads are discharged to Buffalo Bayou and Sims Bayou and these bayous are tributary to that portion of the Houston Ship Channel where D.O. levels are critical, modifications in the model's structure are recommended to accommodate point source discharges to tributaries and thus improve the continuity and predictive accuracy of the model.

6) Further verification of the steady-state model with emphasis on nitrogenous and benthic oxygen demand is recommended.

7) Based on the results of the segment analysis, there is an existing severe wet weather water quality problem on the Houston Ship Channel that gradually worsens throughout the planning period. Many portions of this segment contain less than 1.0 mg/l dissolved oxygen. Fecal coliform concentrations, however, are not excessive.

8) Urban runoff constitutes the majority of the wet weather wasteloads.

9) Stormwater treatment is the only control technique applicable to an existing problem in a heavily populated area that provides the necessary wasteload reductions. This control strategy requires huge expenditures to implement.

10) Prior to incurring the expense of control strategies, the magnitude of the wet weather water quality problem should be determined with instream water quality monitoring. This step should be taken immediately due to its impact on the implementation of dry weather controls. If wet weather water quality is found to be as poor as modeling effots indicate, control strategies should be implemented or the water uses of the segment redefined. If monitoring indicates a water quality problem less severe than initially predicted, verification of the simulation model and loadings should be obtained and approproate control strategies implemented.

11) Additional conclusions and recommendations are included in Chapter VI which presents the evaluation of segment 1005 of the Houston Ship Channel.

Buffalo Bayou

Description of Area

Buffalo Bayou headwaters originate near the City of Katy. The main channel begins approximately 20 miles west of downtown Houston. The bayou flows in an easterly direction for approximately 50 miles before converging with the Houston Ship Channel. This bayou is one of Houston's major transport vehicles for urban runoff.

Much of the area adjacent to the stream has remained in a natural state and is considered a scenic and recreational attraction of the City. The bayou is a focal point of the City's park system with a landscaped parkway along its banks through the center of town. Residential areas are also centered around the bayou's natural setting. Buffalo Bayou holds historic importance to the City of Houston, as well. Many festivities are held at the point in downtown Houston marking the landing of the City's founders.

Results of Dry Weather Segment Analysis

Water quality in Buffalo Bayou is simulated with the SAC III model, as previously defined in Chapter II.

The water quality levels addressed for this stream segment are listed in Table V-4 below.

TABLE V-4

WATER QUALITY LEVELS
BUFFALO BAYOU

Level	D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
I	As available from existing effluent sets.	As available from existing effluent sets.
II	2.0	< 2,000
III	5.0	< 200

All treatment plants on Buffalo Bayou are permitted at effluent set 2, with the exception of City of Houston's Northside/69th Street complex which is permitted at effluent set 2N. Projected water quality is simulated based on these treatment levels and the 1995 projected waste flows.

The basin is divided into 7 geographical planning areas. Three regionalization concepts are analyzed based on the geographical planning areas developed and the City of Houston's current 201 Facility Planning efforts. The location of each area and its relationship to the various regionalization concepts is indicated in Exhibits V-2 through V-4.

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain a dissolved oxygen concentration of approximately 3.0 to 4.0 mg/l at the critical points in the stream. Projected levels of fecal coliform remain below 200 MPN/100 ml. Critical points in the bayou occur downstream of major point source dischargers located in the upper twenty-five miles of the stream where background flows are minimal compared to effluent wasteloads.

Conceptual results of the segment analysis are presented in Table V-5 along with the initial evaluation of pollution control themes. Except where otherwise stated, it is assumed that the majority of the future population is served by centralized treatment systems as opposed to septic tank systems.

TABLE V-5

BUFFALO BAYOU SEGMENT ANALYSIS

Segment: Unclassified, low flow

Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
		D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
All future wasteloads at effluent set 2, except Northside/69th Street STP at 2N.	Existing Technology	3.0	< 200
Reduce wasteload to stream	Increase level of effluent treatment, interbasin transport, land application.	5.0	< 200

Analysis of Themes

Several wasteload control themes are available to meet the desired water quality as specified in the segment analysis. The themes analyzed and their rejection or acceptance for additional study is presented below:

Theme	Description
1	Continue operation of existing plants at permitted levels. New population served by septic tank systems. This theme was rejected for further study because the future population cannot feasibly be served by septic tanks.
2	Continue operation of existing plants at permitted levels (Northside at set 2N, all others at set 2). Construct new plants for operation at effluent set 2. This theme was accepted for further study.
3	Reduce effluent wasteload by upgrading treatment efficiency. This theme was accepted for further study.
4	Reduce effluent wasteload by utilizing land application techniques for major discharges. This theme was rejected because land disposal is not considered feasible in this portion of the study area due to poor soil conditions and lack of sufficient land in an urbanized area.
5	Reduce effluent wasteload by utilizing interbasin transport of major dischargers. This theme was rejected since water quality in other nearby watersheds does not allow for additional wasteloads.

Discussion of Themes Evaluated

Theme 2 is a continuation of the existing level of technology for the stream segment. By definition, Theme 2 produces Water Quality Level I. In Buffalo Bayou, the projected dissolved oxygen concentration resulting from Theme 2 is approximately 3.0 mg/l at critical points in the stream. Fecal coliform concentrations remain below 200 MPN/100 ml. These low dissolved oxygen concentrations are detrimental to the fishlife and recreational potential of the bayou.

The water quality produced by continuing the existing permitted conditions exceeds the criteria defined by Water Quality Level II (see Table V-4). The cost associated with Theme 2 is indicative of the cost for providing sewage treatment services to the existing and future projected population in the basin without regard to the desired fishable/swimmable water quality criteria.

Theme 3 requires upgrading the level of treatment in problem areas indicated in the segment analysis to improve water quality in Buffalo Bayou. Theme 3 was evaluated for the nonregional concept but is equally applicable to the semi-regional and regional concepts. In order to achieve the criteria specified by Water Quality Level III, major dischargers in geographical planning area BB-2 (WCID 134) require upgrading from effluent set 2 to effluent set 2N, and plants in geographical planning area BB-5 (West District) require upgrading from effluent set 2 to effluent set 4N.

The cost associated with Theme 3 includes the cost to provide sewage treatment to the projected population plus the cost to obtain the desired water quality criteria (D.O. = 5.0 mg/l and fecal coliform $<$ 200 MPN/100 ml).

The stream segment profiles depicting D.O. concentrations for themes/concepts described are presented in Appendix B, Figures V-12 through V-15.

Table V-6 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE V-6

COMPARISON OF THEMES/CONCEPTS
BUFFALO BAYOU

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
2	Nonregional (A)	I, II	17	$80,500,000
2	Semi-regional (B)	I, II	7	86,500,000
2	Regional (C)	I, II	5	87,300,000
3	Nonregional (A)	III	17	85,300,000

Results of Wet Weather Segment Analysis

A wet weather water quality simulation model has not been developed specifically for Buffalo Bayou. One junction of the bayou is included in the Houston Ship Channel WRECEV model. This junction is located approximately three miles upstream of the Turning Basin at the confluence of Buffalo and White Oak Bayous.

The simulation model indicates that dissolved oxygen never drops below 5.0 mg/l and fecal coliform concentrations do not exceed 200 MPN/100 ml at this location on Buffalo Bayou during wet weather. Although this single junction cannot be considered as representative of the entire stream segment, preliminary indications are that wet weather quality may not be a problem. Maintenance of good water quality during wet weather conditions is possibly provided by discharges from Addicks and Barker Reservoirs. It is anticipated that sedimentation processes in these reservoirs may produce a relatively high quality discharge.

Quantification of wet weather water quality on Buffalo Bayou is an important step in defining water uses of the segment. Dry weather control themes are designed to preserve the bayou as a fishable/swimmable stream. Prior to incurring the expense of dry weather controls, verification of stream conditions is recommended. An instream monitoring program is recommended to determine the existence or nonexistence of a wet weather water quality problem. Should marginal water quality be indicated, a monitoring program will also provide a reliable data base of wet weather conditions for future studies.

Discussion

Buffalo Bayou water quality is not projected to achieve the fishable/swimmable water quality criteria during dry weather conditions. The results are based on a nonspecific simulation model that is neither calibrated nor verified for the stream. Due to the following considerations not accounted for in the simulation model, it is anticipated that actual water quality will be less than the model's predictions:

1. The natural state of the bayou with heavy vegetation will contribute nonpoint source organic wasteloads to the bayou.

2. During dry weather conditions, the bayou flow is heavily dominated by sewage treatment plant effluent.

3. The predicted water quality is very sensitive to the ammonia-nitrogen concentration in treatment plant effluent which may exceed the assumed value of 8.0 mg/l.

4. Major loadings of nonpoint source suspended solids from stormwater runoff may contribute to a presently undefined benthic oxygen demand.

The above considerations coupled with the presently unverified wet weather water quality does not provide sufficient input to recommend classifying the Bayou for fishable/swimmable uses. However, the Bayou is a focal point of the City and considerable public interest has been generated in its water quality. Therefore, water quality consistent with noncontact recreation and preservation of bayou aesthetics should be determined and Buffalo Bayou should be classified between the Turning Basin and Barker Dam for those uses.

Water quality simulation models should be developed for the bayou. If possible, the Houston Ship Channel model should be extended to include the bayou. Wet weather water quality should also be monitored and wet weather standards consistent with noncontact recreational activities should be defined.

Conclusions and Recommendations

1) Based on the results of the segment analysis, continuation of the existing level of technology will not obtain fishable/swimmable water quality in the stream segment.

2) Buffalo Bayou is Houston's major stream segment holding recreational, scenic, and historic importance to the City. In order to preserve the bayou for these uses, it is recommended that Buffalo Bayou be considered for classification by the TDWR for noncontact recreation and preservation of aesthetics.

3) A specific model should be developed or the Houston Ship Channel model should be expanded to include Buffalo Bayou. Wasteload allocations consistent with water quality standards for noncontact recreation can then be determined.

4) Wet weather water quality should be monitored to verify existing assumptions. Wet weather standards consistent with noncontact water quality should be defined.

Other Tributaries of the Houston Ship Channel

Description of Area

The tributaries of the Houston Ship Channel to be analyzed in this section include Brays Bayou, Sims Bayou, Hunting Bayou, Vince Bayou, Greens/Halls Bayou, and Carpenter Bayou. Except for the upper reaches of Greens/Halls and Carpenter Bayous, all of these stream segments flow through the heavily urbanized Houston metropolitan area (see Exhibit V-1). Dry weather flows in these stream segments consist largely of wastewater return flows. Several of the bayous have been lined with concrete to prevent flooding conditions. None of these streams hold significant potential for recreational uses.

Results of Dry Weather Segment Analysis

Water quality is simulated in all of the bayous with the SAC III model as previously defined in Chapter II. The water quality levels addressed for these stream segments are listed in Table V-7 below.

TABLE V-7

WATER QUALITY LEVELS
HOUSTON SHIP CHANNEL TRIBUTARIES

Level	D.O. (mg/l)	Fecal Coliform MPN/100 ml
I	As available from existing effluent sets.	As available from existing effluent sets.
II	2.0	< 2,000
III	5.0	< 200

All treatment plants on these bayous are permitted at effluent set 2, with the exception of the City of Houston's Sims Bayou plant which is permitted at effluent set 2N. Water quality is simulated based upon these existing treatment levels and the 1995 projected waste flows.

The basins are divided into the geographical planning areas shown on Exhibits V-2 through V-4. Three regionalization concepts are analyzed based on the geographical planning areas developed and the City of Houston's current 201 Facility Planning efforts. Each area's relationship to the various regionalization concepts is also indicated,

The results of the initial dry weather segment analysis indicate that the future water quality during low flow conditions will maintain the dissolved oxygen concentrations shown in Table V-8. Projected levels of fecal coliform remain below 200 MPN/100 ml. Critical points in the bayous typically occur downstream of major dischargers where background flows are minimal compared to effluent wasteloads, and where flows in the stream consist almost entirely of waste flows.

Conceptual results of the segment analysis for each bayou are presented in Table V-9 along with the initial evaluation of pollution control themes. The only theme evaluated for reduction of wasteloads is upgrading treatment efficiency. As discussed in the next section, land application techniques and interbasin transport are unacceptable control themes in the Houston metropolitan area.

Analysis of Themes

Several wasteload control themes are available to meet the desired water quality as specified in the segment analysis. The themes analyzed and their rejection or acceptance for additional study is presented below:

Theme	Description
1	Continue operation of existing plants at permitted levels. New population served by septic tank systems. This theme was rejected for further study because the future population cannot feasibly be served by septic tanks.
2	Continue operation of existing plants at permitted levels (Sims Bayou STP at set 2N, all others at set 2). Construct new plants for operation at effluent set 2. This theme was accepted for further study.
3	Reduce effluent wasteload by upgrading treatment efficiency. This theme was accepted for further study.
4	Reduce effluent wasteload by utilizing land application techniques for major discharges. This theme

TABLE V-8

SEGMENT ANALYSIS - HOUSTON SHIP CHANNEL TRIBUTARIES

Segments: Unclassified, low flow

Bayou	Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
			D.O. (mg/1)	Fecal Coliform (MPN/100 ml)
White Oak	All future wasteloads at effluent set 2.	Existing Technology	2.5 - 3.0	< 200
	Reduce wasteload to stream.	Increase level of treatment.	4.5	< 200
Brays	All future wasteloads at effluent set 2.	Existing Technology	3.0 - 3.5	< 200
	Reduce wasteload to stream.	Increase level of treatment.	5.0	< 200
Sims	All future wasteloads at effluent set 2, except Sims Bayou STP at 2N.	Existing Technology	3.5	< 200
	Reduce wasteload to stream.	Increase level of treatment.	4.0	< 200
Vince	All future wasteloads at effluent set 2.	Existing Technology	2.5	< 200
	Reduce wasteload to stream.	Increase level of treatment.	5.0	< 200

TABLE V-8 (Continued)

Bayou	Effluent Load	Means of Achieving Effluent Load	Resultant Quality	
			D.O. (mg/l)	Fecal Coliform (MPN/100 ml)
Hunting	All future wasteloads at effluent set 2.	Existing Technology	4.0	< 200
	Reduce wasteload to stream.	Increase level of treatment.	5.0	< 200
Greens/Halls	All future wasteloads at effluent set 2.	Existing Technology	3.0 - 4.0	< 200
	Reduce wasteload to stream	Increase level of treatment.	4.5 - 5.0	< 200
Carpenter	All future wasteloads at effluent set 2.	Existing Technology	2.0	< 200
	Reduce wasteloads to stream.	Increase level of treatment.	4.0	< 200

was rejected because land disposal is not considered feasible in this portion of the study area due to poor soil conditions and lack of sufficient land in urbanized areas.

5 Reduce effluent wasteload by utilizing interbasin transport of major dischargers. This theme was rejected since water quality in other nearby watersheds does not allow for additional wasteloads.

Discussion of Themes Evaluated

Theme 2 is a continuation of the existing level of technology for the stream segment. By definition, Theme 2 produces Water Quality Level I. As shown on Table V-8, the projected dissolved oxygen concentration resulting from Theme 2 ranges from 2.0 to 4.0 mg/l in the various bayous. All of the bayous with the exception of Hunting Bayou exhibit D.O. concentrations less than 4.0 mg/l. Fecal coliform concentrations remain below 200 MPN/100ml.

The water quality produced by continuing the existing permitted conditions exceeds the criteria defined by Water Quality Level II (see Table V-7) . The cost associated with Theme 2 is indicative of the cost for providing sewage treatment services to the existing and future projected population in the basin without regard to the desired fishable/swimmable water quality criteria.

Theme 3 requires upgrading the level of treatment in problem areas indicated in the segment analysis to improve water quality in the bayous. Theme 3 is evaluated for the nonregional concept but is equally applicable to the semi-regional and regional concepts. The simulation model determines the necessary reductions in BOD wasteloads to achieve Water Quality Level III. However, in several instances the maximum defined level of sewage treatment (4N) will not provide the necessary reductions to achieve a D.O. concentration of 5.0 mg/l in the stream. The plants in geographical planning areas that require upgrading and the necessary level of treatment are indicated in Table V-9 for each bayou.

The cost associated with Theme 3 includes the cost to provide sewage treatment to the projected population plus the cost to obtain the desired water quality criteria (D.O. = 5.0 mg/l and fecal coliform <200 MPN/100 ml).

The stream segment profiles depicting D.O. concentrations for themes/concepts described are presented in Appendix B , Figures V-16 through V-40.

TABLE V-9

THEME 3 -- HOUSTON SHIP CHANNEL TRIBUTARIES

Bayou	Geographical Planning Area	Treatment Plants	Upgraded Level of Treatment
White Oak	WO-1	HC FWSD 61	2N
	WO-4	Northwest	4N*
Brays	BrB-1	Westheimer MUD	2N
	BrB-1	HC FWSD 63**	reduce 23%
	BrB-1	HC WCID 78	3N
	BrB-1	HC WCID 94	3N
	BrB-1	Beltway MUD	3N
	BrB-1	Manning MUD	3N
	BrB-2	Southwest	4N
Sims	SB-1	WCID 51	4N
	SB-2	Almeda Sims	4N*
Vince	VB-1	Pasadena 1A & 1B	3N
Hunting	HB-1	Homestead	3N
Greens/Hall	G/HB-4	Future plant	4N*
	G/HB-3	North Gate	3N
	G/HB-3	Imperial Valley	3N
	G/HB-3	West Road UD	3N
Carpenters	CB-1	HC FWSD 47	4N*
	CB-1	HC FWSD 6	2N

* Maximum defined level of treatment does not achieve Water Quality Level III.

** Industrial wasteload.

Table V-10 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE V-10

COMPARISON OF THEMES/CONCEPTS
HOUSTON SHIP CHANNEL TRIBUTARIES

Bayou	Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
White Oak	2	Nonregional (A)	I, II	11	$33,300,000
	2	Regional (C)	I, II	3	33,200,000
	3	Nonregional (A)	I, II*	11	36,200,000
Brays	2	Nonregional (A)	I, II	24	49,800,000
	2	Semi-Regional (B)	I, II	4	56,300,000
	2	Regional (C)	I, II	3	50,800,000
	3	Nonregional (A)	III	24	62,400,000
Sims	2	Nonregional (A)	I, II	14	80,900,000
	2	Regional (C)	I, II	7	80,700,000
	3	Nonregional (A)	I, II*	14	92,700,000
Vince	2	Nonregional (A)	I, II	3	7,900,000
	3	Nonregional (A)	III	3	9,400,000
Hunting	2	Nonregional (A)	I, II	5	5,200,000
	2	Semi-Regional (B)	I, II	2	5,000,000
	2	Regional (C)	I, II	1	4,900,000
	3	Nonregional (A)	III	5	6,800,000
Greens/ Halls	2	Nonregional (A)	I, II	27	44,700,000
	2	Semi-Regional (B)	I, II	6	50,700,000
	2	Regional (C)	I, II	5	51,800,000
	3	Nonregional (A)	I, II*	27	45,500,000
Carpenters	2	Nonregional (A)	I, II	3	2,000,000
	2	Regional	I, II	1	2,100,000
	3	Nonregional (A)	I, II*	3	3,100,000

*Maximum defined level of treatment improves water quality but does not achieve Water Quality Level III.

Results of Wet Weather Segment Analysis

There is no stormwater model available to evaluate the water quality of the bayous during wet weather conditions. However, the bayous main purpose is to convey storm water runoff out of the area and prevent flooding. Since urban runoff will dominate, it is likely that poor water quality will prevail.

Discussion

The bayous discussed herein are projected to maintain a water quality of less than the defined fishable/swimmable criteria. These conditions are based on a nonspecific simulation model that is neither calibrated nor verified. Shortcomings of the modeling technique discussed in the Buffalo Bayou section are also relevant to these remaining bayous.

The bayous discussed in this chapter are effluent dominated during dry weather and stormwater dominated during wet weather, that has been the purpose for which they are maintained. Therefore, these bayous should not become classified stream segments and should not attempt to meet fishable/swimmable water quality. An attempt should be made to keep fecal coliform concentrations below 200 MPN/100 ml.

Conclusions and Recommendations

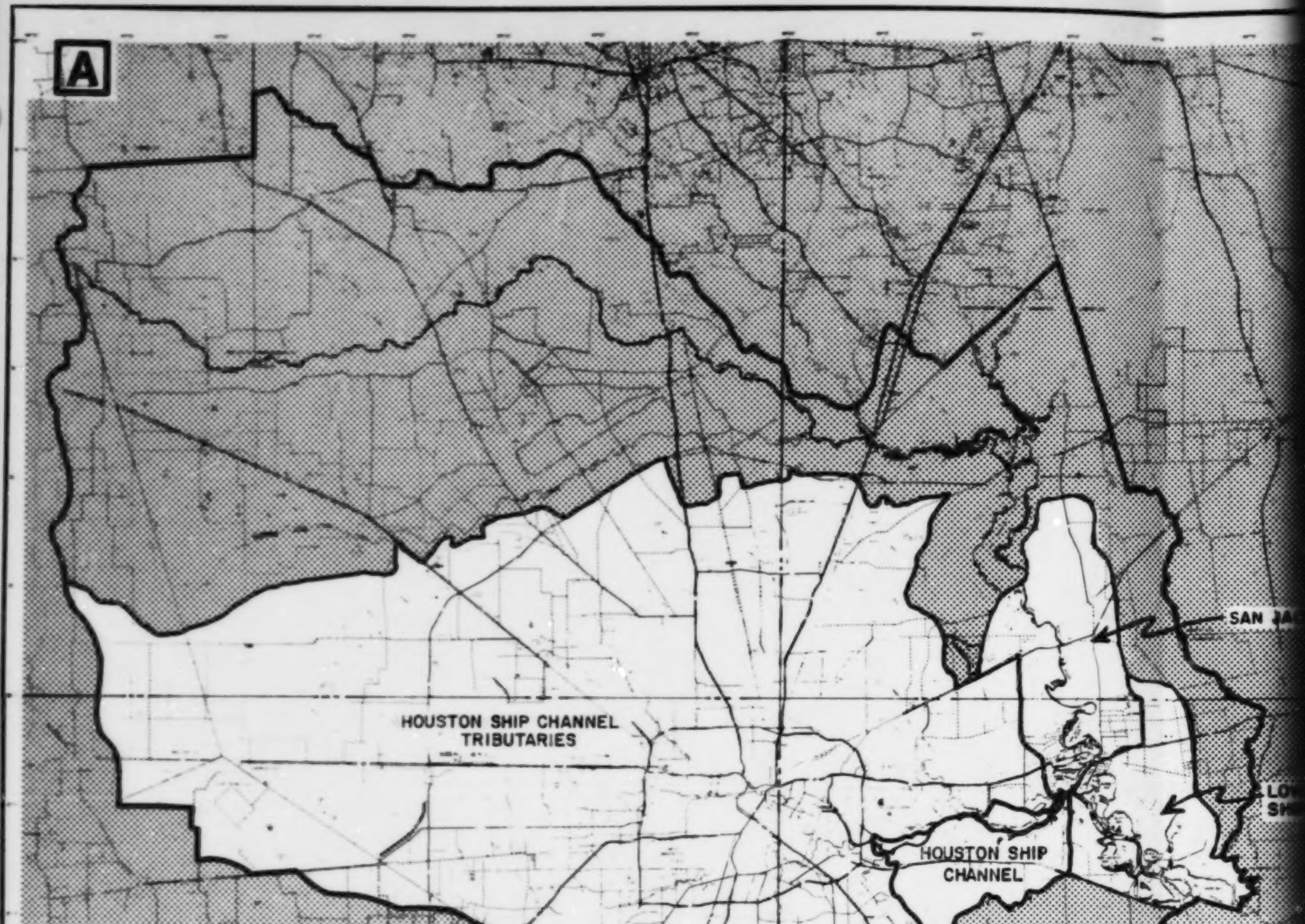
1) Based on the results of the segment analysis, continuation of the existing level of technology will not obtain fishable/swimmable water quality in the bayous.

2) The total present worth cost for implementing the nonregional concept of Theme 3 is estimated to be $32,300,000 more than Theme 2.

3) As mentioned in the segment analysis for the Houston Ship Channel, continuation of existing technology on the bayous results in a dissolved oxygen concentration of 4.0 mg/l at the critical point (turning basin). Upgrading the major dischargers on Buffalo and Sims Bayous to the maximum level of treatment (4N) does not significantly raise the D.O. concentration in the Ship Channel. Therefore, upgrading the quality of the bayous does not significantly improve the quality of the Houston Ship Channel.

4) The objective of the 208 program has been to bring water quality of the streams in the 208 area to fishable/swimmable conditions. However, since White Oak, Brays, Sims, Vince, Hunting, Greens/Halls, and Carpenters Bayous consist largely of wastewater return flows during dry weather conditions and stormwater runoff during wet weather conditions, they do not hold a significant recreational

potential. It is recommended that the extreme cost of bringing water quality to fishable/swimmable conditions be avoided and treatment plants continue to operate at their existing permitted levels.


A
SAN JA
HOUSTON SHIP CHANNEL TRIBUTARIES
LOW
SH
HOUSTON SHIP CHANNEL
C
208 PLANNING AREA
DRAINAGE BASINS
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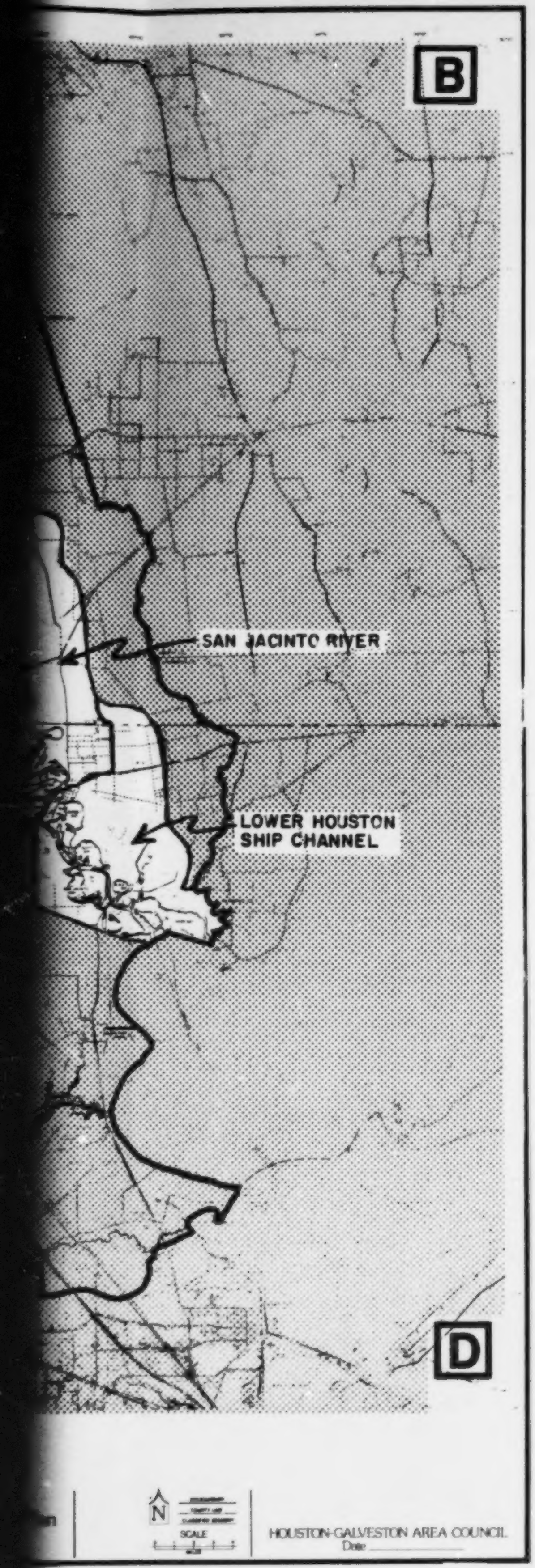
A B
C D
N
SCALE

Areawide Waste Treatment Management Plan
HOUSTON AREA


B
SAN JACINTO RIVER
LOWER HOUSTON SHIP CHANNEL
D
N
SCALE
HOUSTON-GALVESTON AREA COUNCIL
Date

GREATER HOUSTON 208 PROGRAM

HOUSTON-GALVESTON AREA COUNCIL

HOUSTON SHIP CHANNEL & TRIBUTARIES

TECHNICAL SUBPLANNING AREA

DRAWN BY: ROY F WESTON DATE:	REVISIONS BY: DATE:	EXHIBIT V-I SCALE SECTION

CHAPTER VI - SAN JACINTO RIVER (TIDAL)/ HOUSTON SHIP CHANNEL AND ADJOINING BAYS CONFLUENCE WITH THE SAN JACINTO RIVER TO MORGAN'S POINT

CHAPTER VI - SAN JACINTO RIVER (TIDAL)/ HOUSTON SHIP CHANNEL AND ADJOINING BAYS CONFLUENCE WITH THE SAN JACINTO RIVER TO MORGAN'S POINT

Introduction

The San Jacinto technical subplanning area is located along the eastern edge of the 208 planning area (see Exhibit VI-1). The major tidal waterways within this area are the Houston Ship Channel and the San Jacinto River. For ease of discussion, the San Jacinto River and Houston Ship Channel Segments are addressed individually.

Houston Ship Channel and Adjoining Bays Confluence with the San Jacinto River to Morgan's Point

Description of Area

The Houston Ship Channel from the confluence with the San Jacinto River to Morgan's Point constitutes the lower portion of the waterway within the subplanning area. It is classified as Segment 1005 by the Texas Water Quality Board. Adjoining this reach are a number of large bays. These include Burnett Bay (Segment 2430), Scott Bay (Segment 2429), Black Duck Bay (Segment 2428), San Jacinto Bay (Segment 2427) and Tabbs Bay (Segment 2436).

Land use along Segment 1005 is primarily residential and industrial. Some undeveloped areas exist in the vicintities of Tabbs Bay and San Jacinto Bay. Industrial development is generally confined to Scott Bay, Black Duck Bay, and San Jacinto Bay. Residential, open and park space typify the development status of the San Jacinto River confluence, Burnett Bay and Scott Bay areas. Significant deviations from this pattern are not projected for 1995.

Results of Dry Weather Segment Analysis

The Houston Ship Channel Water Quality Simulation Model as discribed in Chapter II is utilized for the dry weather segment analysis. Waste input to the model follows the procedure outlined in Chapter 5.

The Water Quality Levels addressed for Segment 1005 are presented in Table VI-1.

Water Quality levels addressed for bays adjoining this segment of the Houston Ship Channel are presented in Table VI-2.

TABLE VI-1

WATER QUALITY LEVELS - SEGMENT 1005
HOUSTON SHIP CHANNEL
(SAN JACINTO RIVER CONFLUENCE TO MORGAN'S POINT)

Level	D.O. (mg/l)	Fecal Coliform MPN/100 ml
I	As available from existing permitted effluent sets	As available from existing permitted effluent sets
II	4.0	< 1000
III	5.0	< 200

TABLE VI-2

WATER QUALITY LEVELS
TABBS BAY, SAN JACINTO BAY, BLACK DUCK BAY, SCOTT BAY, BURNETT BAY

Bay		Dissolved Oxygen (mg/l)			Fecal Coliform MPN/100 ml		
Name	TWQB Segment No.	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Tabbs	2426	*	4	5	*	< 200	< 200
San Jacinto	2427	*	4	5	*	< 200	< 200
Black Duck	2428	*	4	5	*	< 200	< 200
Scott	2429	*	4	5	*	< 200	< 200
Burnett	2430	*	4	5	*	< 200	< 200

*As available from existing permitted effluent sets.

The basin is divided into 5 geographical planning areas by the methods discussed previously. The location of each area and the manner in which they are combined for regionalization concepts are indicated on Exhibits V-2 through V-4. Projected water quality for these concepts is outlined below.

The results of the initial dry weather segment analysis indicate that future water quality, during low flow conditions, will maintain a dissolved oxygen concentration greater than 5.0 mg/l in segment 1005 of the Houston Ship Channel. Based on data currently available, the model predicts a continuous improvement from 5.3 mg/l D.O. at the confluence with the San Jacinto River to 7.0 mg/l D.O. at Galveston Bay. The expected D.O. levels in the adjoining bays are: Black Bay 6.9 mg/l; Tabbs Bay 6.9 mg/l; Scott Bay 6.2 mg/l; and Burnett Bay 5.6 mg/l. No variations in D.O. concentrations are established within the bays since each bay is treated as completely mixed in the simulation. Figure VI-1, Appendix B , depicts the predicted D.O. profile along Segment 1005 for the nonregional concept. Similar profiles are predicted for the other two concepts.

The distribution of waste loads input into the Houston Ship Channel and its tributaries and the oxygen supply potential of Galveston Bay account for the D.O. profile being insensitive to the regionalization concepts. The bulk of municipal and industrial point source inputs are above the confluence with the San Jacinto River. The water quality entering Segment 1005 from the Upper Houston Ship Channel improves substantially from the deficit induced by these loads at the Turning Basin and the background benthic demand along the segment. Oxygen consumption, associated with wastes discharged below the confluence, is not sufficient to reverse the recovery process or strongly inhibit upstream tidal dispersion of dissolved oxygen from Galveston Bay.

Additional conclusions developed in the segment analysis are:

(1) For dry weather conditions, nonpoint source wasteloads are not significant.

(2) Projected levels of fecal coliform remain below defined water quality criteria since treatment plants are assumed to discharge no more than 200 MPN/100 ml and nonpoint source wasteloads are insignificant. Dilution and degradation in the stream keep concentrations well below 200 MPN/100 ml.

Analysis of Themes

Based on simulation modeling techniques and available data, the water quality projections for the lower Houston Ship Channel and Segments 2426, 2427, 2428, 2429, and 2430 meet or exceed fishable/swimmable criteria of Water Quality Level III. Therefore, the lower Houston Ship Channel and its adjoining bays meet the desired water quality and require no further analysis. The only theme to be evaluated is the theme that calls for a continuation of the existing level of technology, as described below:

Theme	Description
1	Continue operation of existing plants at effluent set 2. Construct any future facilities for operation at effluent set 2.

Discussion of Themes Evaluated

By definition, continuation of the existing level of technology produces Water Quality Level I in the segment. However, in this case, the resulting water quality meets or exceeds the water quality criteria specified by Levels II and III. The costs associated with this theme are indicative of the costs to provide sewage treatment to the existing and future projected population in the basin.

Model results indicate that the lower Houston Ship Channel has excess assimilative wasteload capacity. Increasing the pounds per day input of carbonaceous and nitrogenous BOD by 300 percent, effects a fairly uniform change in the water quality of the Houston Ship Channel. At Morgan's Point, the model predicts the D.O. level will drop from 7.0 mg/l to 6.7 mg/l (see Figure VI-2). The critical point in segment 1005 remains at the confluence with the San Jacinto River where the dissolved oxygen concentration is computed to be 5.0 mg/l. Water Quality Level III is achieved, despite the increased wasteload.

While dilution from adjoining bays helps minimize the impact of municipal and industrial effluents discharged below the San Jacinto River, tidal dispersion transports some of the waste material back upstream to the Turning Basin. Consequently, increasing the intensity of wasteload to segment 1005 further degrades the water quality in segments 1006 and 1007. Because these segments experience a critical D.O. level, the effectiveness of the themes discussed in Chapter V are re-evaluated with respect to the use made of the assimilative wasteload capacity of the lower Houston Ship Channel.

Based on the modeled inputs, Theme 1 and Theme 2 for segments 1006 and 1007 easily achieve Water Quality Level II criteria but are more than 0.5 mg/l D.O. below the criteria of Water Quality Level III. The Houston Ship Channel Water Quality Simulation Model predicts that a 300 percent increase in the carbonaceous and nitrogenous inputs to segment 1005 lowers the D.O. level at the Turning Basin only 0.2 mg/l due to tidal dispersion effects (Figure VI-2). This additional deficit is not sufficient to reduce the dissolved oxygen concentration Water Quality Level II criteria.

Theme 3 achieves Water Quality Level III in segments 1006 and 1007 by utilizing instream aeration to augment oxygen supply in critical areas. Based on model results, increasing the wasteload entering segment 1005 by 300 percent requires a greater degree of instream aeration to preserve Water Quality Level III at the Turning Basin. The total oxygen requirement due to the 300 percent increase in wasteload is approximately 11,000 pounds per day at the Turning Basin and 10,000 pounds per day in the vicinity of Brays Bayou, an increase of approximately 3,000 pounds per day over the requirements due to the initially projected wasteloads. As shown on Figure VI-3, the minimum predicted D.O. is approximately 5.0 mg/l and is located in the vicinity of Sims Bayou.

Table VI-3 presents the themes/concepts evaluated and the estimated present worth costs for implementation.

TABLE VI-3

COMPARISON OF THEMES/CONCEPTS
LOWER HOUSTON SHIP CHANNEL AND ADJOINING BAYS

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional	III	11	$18,800,000
1	Regional	III	5	21,500,000

Discussion

The segments 1006 and 1007 of the Houston Ship Channel have been discussed in Chapter V. Segment 1005 is projected to maintain a water quality in excess of the fishable/swimmable criteria during dry weather, based on the calibrated and verified simulation model. Wet weather water quality is projected to be very poor as discussed in Chapter V.

Of major interest in Segment 1005 is the excess assimilative capacity for oxygen demanding wasteloads as predicted by the steady-state model. The effects of increasing the projected wasteload to Segment 1005 by an additional 300 percent are minor. The dissolved oxygen concentration in Segment 1005 will be reduced but is still projected to remain above the fishable/swimmable criteria. The dissolved oxygen concentration in Segments 1006 and 1007 are projected to be reduced due to tidal dispersion effects. The dissolved oxygen concentration at the Turning Basin, due to the increased wasteload from Segment 1005, is projected to be 3.9 mg/l, a decrease of 0.2 mg/l, as compared to the dissolved oxygen concentration without the increased wasteloads.

Theme 3 in Chapter V indicates that Water Quality Level III can be achieved during dry weather through supplemental aeration techniques. The oxygen requirement is estimated at 18,000 pounds per day. If the wasteload to Segment 1005 is increased by 300 percent, the oxygen required to achieve the fishable/swimmable water quality is estimated at 21,000 pounds per day, an increase of only 3,000 pounds per day.

Other items discussed in Chapter V in regard to the Houston Ship Channel are equally relevent to this seciton.

Conclusions and Recommendations

1) Based on the results of the segment analysis, continuation of the existing level of technology results in water quality that meets and exceeds fishable/swimmable standards.

2) The segment analysis further indicates that excess assimilative capacity may be available in this area. Utilizing this segment's excess capacity allows a 300 percent increase in allocated wasteloads. However, due to tidal dispersion this increase in wasteloads in segment 1005 also effects the upper reaches of the Houston Ship Channel. A re-evaluation of control themes for these reaches indicates that Water Quality Level III is maintained by inputting an additional 3,000 pounds per day of oxygen through instream aeration.

3) The segment 1005 D.O. profile is similar for the three regionalization concepts. The wasteload distribution along the Houston Ship Channel from its headwaters to Morgan's Point, the heavy point source discharge to its tributaries, and the dissolved oxygen in Galveston Bay coupled with dispersive mechanisms account for the insensitivity. Upstream waste discharges influence significantly the D.O. deficit at the confluence with the San Jacinto River, the point of lowest predicted D.O. concentration

4) Other conclusions and recommendations are contained in the Houston Ship Channel section of Chapter V.

San Jacinto River (Tidal)
Confluence to Lake Houston Dam

Description of Area

Lake Houston Dam separates the tidal reach of the San Jacinto River from its headwaters and upstream tributaries, and designates the upper boundary of the San Jacinto River within the technical subplanning area. The tidal reach of the San Jacinto River extends in a south-easterly direction from the base of Lake Houston Dam to the confluence with the Houston Ship Channel, approximately 20 miles downstream. Major tributaries to this segment are Jackson Bayou and Granite Spring Creek. During most of the year, 60% of the total freshwater discharge to the Houston Ship Channel is normally via San Jacinto River. However, for extended periods of low flow, the freshwater flow rate from the San Jacinto River may be in the range of 0 to 10 cfs. For the dry weather segment analysis it is assumed no water flows over the Lake Houston Dam spillway and municipal and industrial discharge constitute the net river flow.

Many of the major point source discharges are from municipal plants. Most of these are located along Jackson Bayou, two to eight miles upstream from its confluence with the San Jacinto River. The relatively limited distribution of waste load input to the segment may be attributed to current land use patterns. Several residential communities have developed along the segment. Locally, there are no major farming activities, although large tracts of land remain vacant. Industrial development has not taken place to any great extent. Significant changes in this pattern are not projected for 1995.

Water quality in the upper tidal portion of the San Jacinto River has generally been good. Near the confluence, however, low D.O. levels and high fecal coliform counts have been detected. The problem is particularly acute during conditions of high temperature and low flow. Tidal interchange from the Houston Ship Channel dominates water quality during low flow conditions.

Results of Dry Weather Segment Analysis

The AUTOSS Water Quality Simulation Model is used for the dry weather segment analysis. The model, developed by the Environmental Protection Agency, is a steady-state dispersive model capable of handling carbonaceous and nitrogenous BOD, dissolved oxygen, and conservative substances. Model calibration for the San Jacinto

River was accomplished by the TDWR using 13 January 1976 data. A TDWR sensitivity analysis of model output to changes in input parameters indicates that the dissolved oxygen level at the Houston Ship Channel has the biggest effect on predicted D.O. levels. Model verification, applying different hydraulic and waste input conditions has not been reported.

It should also be noted that benthic demands are not included among the physical parameters incorporated into the calibrated model. Due to the importance of this parameter in other streams in the study area, definition of benthic demand should be included in verification of AUTOSS.

The basin is divided into two geographical planning areas by the methods discussed previously. The location of each area and the manner in which they are combined for the concepts of semi-regionalization and regionalization are indicated on Exhibits VI-2 through VI-4. The results for each concept are outlined below.

The Water Quality Levels addressed for this segment are presented in Table VI-4.

TABLE VI-4

WATER QUALITY LEVELS
SAN JACINTO RIVER (TIDAL)
CONFLUENCE TO LAKE HOUSTON DAM

Level	D.O. (mg/l)	Fecal Coliform MPN/ 100 ml
I	As available from existing permitted effluent sets	As available from existing permitted effluent sets
II	4.0	< 200
III	5.0	< 200

Many of the major municipal plants discharge directly or through channels to Jackson Bayou. In the results reported below, no degradation is applied to account for quality change during travel time from point of discharge to mixing with the San Jacinto River. The wide spatial distribution of municipal discharges to Jackson Bayou renders this a conservative estimate. The oxygen demanding potential of a single equivalent waste discharge, applied at the confluence of the two streams, effectively increases the BOD level applied to the segment.

Projected water quality for the San Jacinto River (tidal) is simulated with steady-state modeling techniques and is based on 1995 future wasteloads and existing permitted levels of wastewater treatment. Projected industrial loads are supplemented by an ammonia-nitrogen load based on 1977 wasteload allocation. Since the waste return flow from the San Jacinto River system (17.51 cfs) is small compared to the total Houston Ship Channel Flow (1800 cfs), dissolved oxygen, carbonaceous BOD and nitrogenous BOD concentrations predicted by the Ship Channel Model at the confluence are used as fixed point boundary conditions in the AUTOSS program.

The results of the initial dry weather segment analysis indicate that future water quality during low flow conditions will maintain a dissolved oxygen concentration greater than 5.0 mg/l. Dissolved oxygen profiles for the three regionalization concepts differ little. This is attributed to the dominate influence of Houston Ship Channel water quality. Concentrations range from 5.3 mg/l D.O. at the Ship Channel to 5.6 mg/l D.O. at Lake Houston Dam (Figure VI-4, Appendix B).

Model results show that for projected 1995 industrial and municipal discharge levels the minimum D.O. level in the San Jacinto River corresponds approximately to the D.O. concentration at the confluence with the Houston Ship Channel.

Additional conclusions developed in the segment analysis are:

1) Projected levels of fecal coliform remain below defined water quality criteria since treatment plants are assumed to discharge no more than 200 MPN/100ml and nonpoint source wasteloads are insignificant. Dilution and degradation in the stream keep concentrations well below 200 MPN/100ml.

2) The only potentially significant nonpoint source wasteloads may be due to dredging activities. Commercial sand dredging is practiced in the segment and subsequent resuspension of settled oxygen demanding material may reduce D.O. concentrations below prescribed water quality level criteria. Current estimates for oxygen demand, created by dredging of sandy bottom channels, is 8,600 pounds per day. This load is substantially larger than the 1995 total projected municipal and industrial waste discharge to the San Jacinto River. Until actual dredging loads are assessed and the potential impact evaluated, scheduled dredging activities should not be performed during critical flow periods.

Analysis of Themes

The water quality projections, based on simulation modeling techniques for the San Jacinto River, meet or exceed the fishable/swimmable criteria of Water Quality Level III. According to model output using data currently available, the San Jacinto River meets the desired water quality and requires no further analysis. The only theme to be evaluated is the theme calling for a continuation of the existing level of technology, as described below:

Theme	Description
1	Continue operation of existing plants at effluent Set 2. Construct any future facilities for operation at effluent Set 2.

Discussion of Themes Evaluated

By definition, continuation of the existing level of technology produces Water Quality Level I in the segment. However, in this case, the resulting water quality meets or exceeds the water quality criteria specified by Levels II and III. The costs associated with this theme are indicative of the costs to provide sewage treatment to the existing and future projected population in the basin.

Table VI-5 presents the theme/concepts evaluated and the estimated present worth costs for implementation.

TABLE VI-5

COMPARISON OF THEMES/CONCEPTS
SAN JACINTO RIVER (TIDAL)

Theme	Concept	Water Quality Level Achieved	Municipal Dischargers Projected	Present Worth Cost
1	Nonregional	III	11	$7,100,000
1	Semi-regional	III	2	8,300,000
1	Regional	III	1	8,800,000

The stream segment profile depicting D.O. concentrations for the nonregional concept are presented in Appendix B, Figure VI-4. Similar profiles exist for the semi-regional and regional concepts.

Results of Wet Weather Segment Analysis

The WRECEV water quality simulation model for the Houston Ship Channel also includes the tidal portion of the San Jacinto River as discussed in Chapter V. The simulation is applied over a twenty day period with the storm occurring in the first hour of the eighth day. Wasteloads and stormwater flows for 1975, 1983, 1990, and 1995 conditions are input to the model at predefined time intervals in specified junctions, as developed in the Nonpoint Source Analysis Report. The model then simulates the resulting stream flow and water quality versus time.

Currently, no standards exist specifically for wet weather situations. Therefore, the initial evaluation of resultant water quality is based upon dry weather standards.

The model predicts that dissolved oxygen concentrations remain above 5.0 mg/l at most junctions on the San Jacinto River from 1975 to 1995. Only one junction, located near the confluence with the Houston Ship Channel, exhibits a low oxygen content. This portion of the San Jacinto River falls as low as 4.0 mg/l D.O. in 1975 and gradually worsens to 3.5 mg/l D.O. in 1995. This segment does not recover to 5.0 mg/l D.O. for eleven to thirteen days following the storm event. Dissolved oxygen profiles are depicted on Figures VI-5 through VI-9.

Fecal coliform concentrations remain below 200 MPN/100 ml during wet weather in all junctions except the one located nearest the Ship Channel. This junction experiences a peak concentration of 2900 MPN/100 ml which rapidly decreases. Concentrations are below 200 MPN/100 ml within three to three and one-half days following the storm.

Based upon the inputs to the water quality simulation model, wet weather conditions on the San Jacinto River are within dry weather standards for fecal coliform in all junctions throughout the planning period. Dry weather standards for dissolved oxygen are violated at only one junction near the confluence with the Ship Channel. Due to tidal actions, the indication of extremely poor wet weather water quality in the Ship Channel (see Chapter V), and the good wet weather water quality in the upper and middle reaches of the San Jacinto River, it is assumed that water quality at this junction is dominated by the water quality of the Ship Channel. Therefore, improved wet weather quality in the lower reaches of the San Jacinto River can be obtained only by controls on stormwater runoff to the Houston Ship Channel.

Conclusions and Recommendations

1) Based on the results of the segment analysis, using data currently available, continuation of the existing level of technology results in water quality that meets or exceeds the goal of fishable/swimmable streams. Therefore, it is recommended that the technical subplan for the San Jacinto River is to continue controlling point source discharges at the existing permitted level.

2) The segment analysis indicates that upgrading the treatment efficiencies of plants discharging to the San Jacinto River has very little effect on its water quality. This segment is dominated by tidal dispersion from the Houston Ship Channel. Therefore, continued use of the San Jacinto River for contact recreation requires maintenance of good water quality in the Houston Ship Channel.

3) Benthic demands are not included among the physical parameters incorporated into the calibrated model. Therefore, field studies should be initiated in the San Jacinto River to:

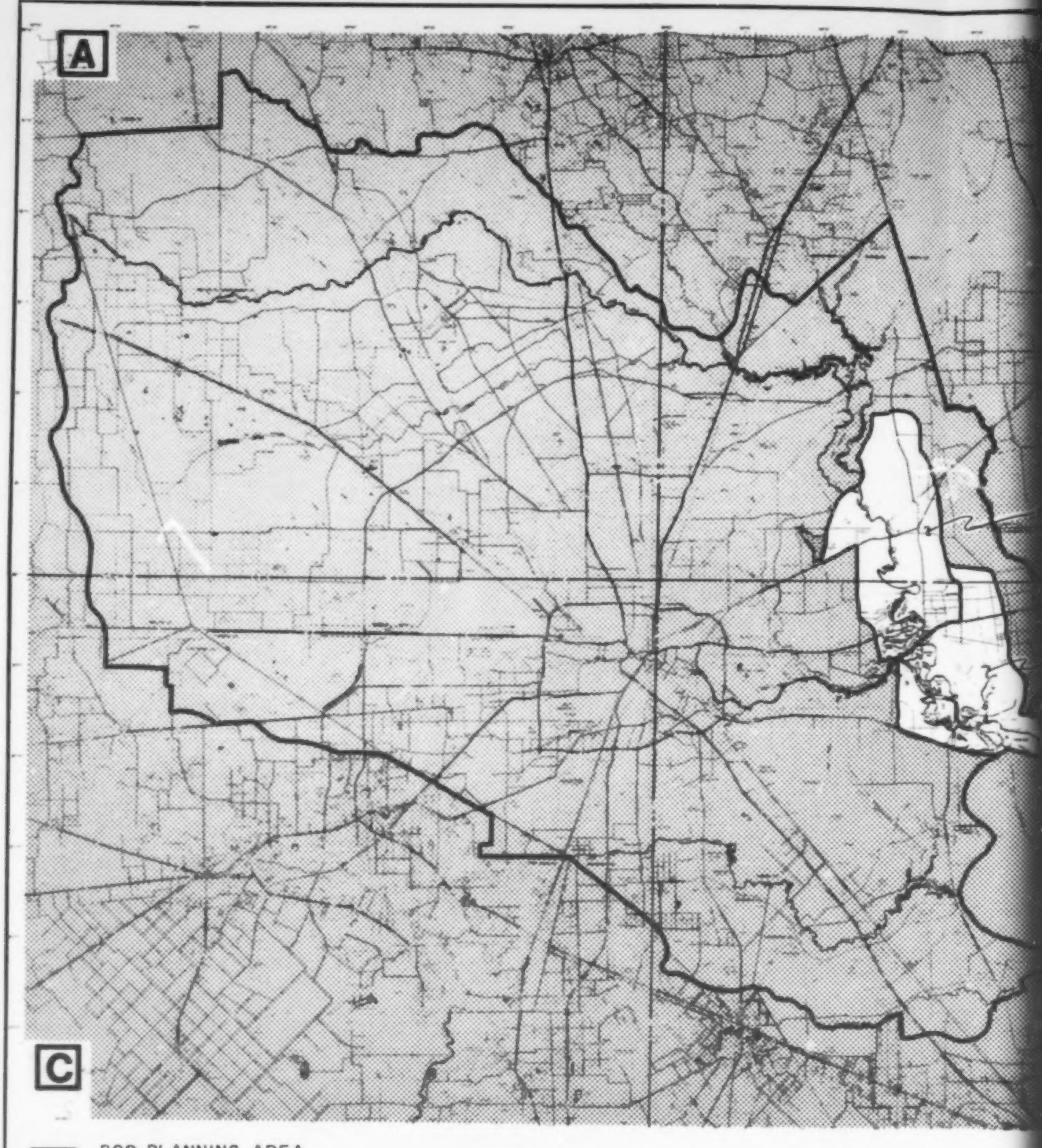
    (i) update the model with respect to benthic demand, and

    (ii) provide an additional data base for verifying the AUTOSS model.

4) Based on the results of the segment analysis, wet weather conditions on the San Jacinto River throughout the planning period are in compliance with dry weather standards for fecal coliform in all junctions and dissolved oxygen in all but one junction nearest the Houston Ship Channel.

5) Due to tidal influences, it is concluded that wet weather water quality in the lower reaches of the San Jacinto River is dominated by the poor wet weather conditions in the Houston Ship Channel. Therefore, control strategies to improve water quality in the lower reaches on the San Jacinto River should be directed at stormwater runoff to the Ship Channel.

6) The stream modeling results are based upon inputs that reflect a first attempt to address wet weather water quality in the H-GAC 208 planning area. At this time the accuracy of the wet weather wasteloads input to WRECEV is not known. Further monitoring is recommended to develop a reliable data base of wet weather conditions on the San Jacinto River.



208 PLANNING AREA
DRAINAGE BASINS

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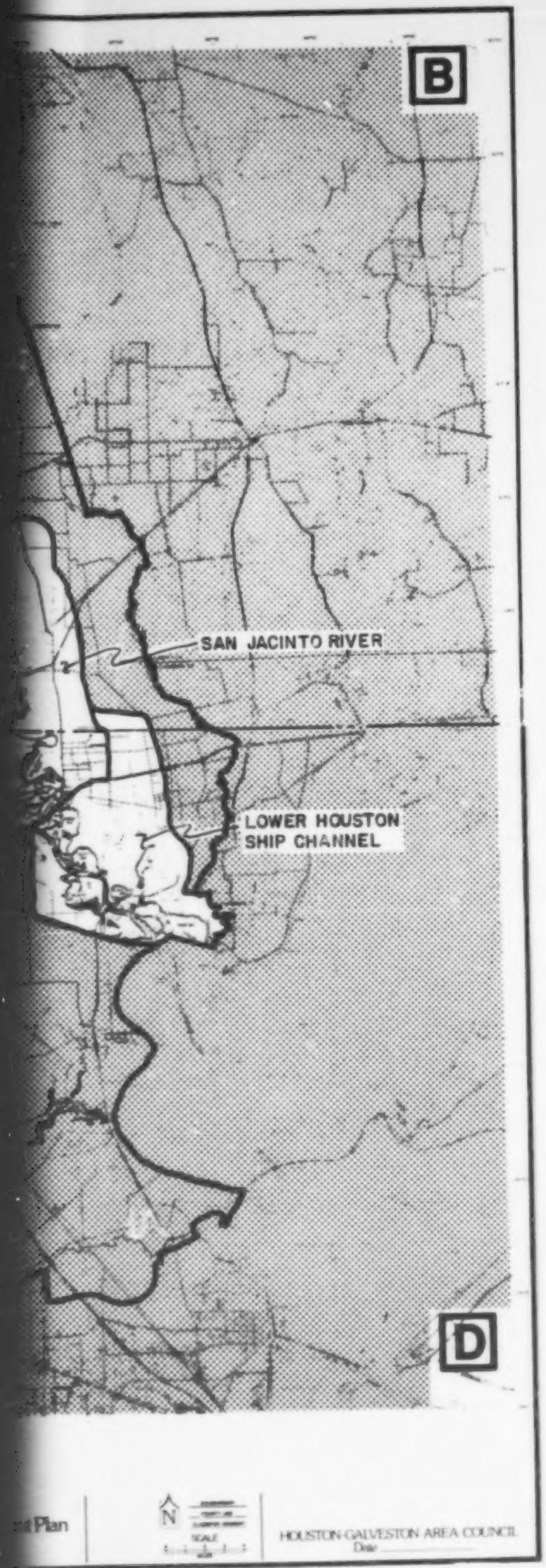
Areawide Waste Treatment Management Plan
HOUSTON AREA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HOUSTON-GALVESTON AREA COUNCIL
Date

GREATER HOUSTON 208 PROGRAM

HOUSTON-GALVESTON AREA COUNCIL

SAN JACINTO RIVER / LOWER HOUSTON SHIP CHANNEL

TECHNICAL SUBPLANNING AREA

DRAWN BY: ROY F. WESTON DATE:	REVISIONS BY: DATE:	EXHIBIT VI-1 SCALE SECTION

CHAPTER VII - GENERAL CONSIDERATIONS FOR ALTERNATIVE TECHNICAL SUBPLANS

CHAPTER VII - GENERAL CONSIDERATIONS FOR ALTERNATIVE TECHNICAL SUBPLANS

General

The analyses and recommendations presented in the previous chapters are based on a compilation of inputs and projections obtained from various sources. Additionally, assumptions have been made in order to coordinate the information into a workable data base. Therefore, the reliability of the alternative technical subplans is sensitive to the data base and assumptions.

This chapter is designed to respond to the reliability and sensitivity of the alternative technical subplans. Additionally, information will be presented herein to address those points which are particular to no specific basin but are important to the H-GAC 208 Planning Area on a whole.

Sensitivity of Model Inputs

General

The segment analyses and alternative technical subplans are based on the results of water quality simulation modeling. Water quality models for the classified segments were provided by the TDWR. Input data and assumptions utilized in assessing the water quality are subject to variances. Therefore, a sensitivity analysis of the most volatile parameters effecting the water quality simulation has been performed for certain classified segments as detailed below.

Spring Creek

Sensitivity analyses were performed on effluent dissolved oxygen concentration, ammonia-nitrogen concentration, and future growth patterns. The results of the sensitivity analysis gave the following results:

1) An effluent dissolved oxygen concentration of 4.0 mg/l was assumed as typical for level 2 treatment in the segment analysis. When this value was altered to 0.0 mg/l or 6.8 mg/l there was a negligible effect on the Spring Creek water quality. The dissolved oxygen in the Creek at the critical point varied by a maximum of 0.2 mg/l.

2) An effluent concentration of 8.0 mg/1 ammonia-nitrogen was assumed in the segment analysis evaluation. When this value was increased to 20.0 mg/1 the dissolved oxygen concentration at the critical point in the stream dropped to less than 3.0 mg/1, a decrease of approximately 2.0 mg/1.

3) To assess the effects of changing growth rates on the simulation model, the projected 1995 wastewater flows were increased by 50 percent. The resultant dissolved oxygen at the critical point in Spring Creek was approximately 4.4 mg/1, or a decrease of approximately 0.5 mg/1 below the segment analysis run.

Based on the Spring Creek sensitivity analysis, projected water quality is most directly related to the variability of the ammonia-nitrogen concentration. The originally assumed value of 8.0 mg/1 in sewage treatment plant effluent for Level 2 treatment was chosen because this is the value utilized by the TDWR in their wasteload evaluation reports. Since this value of 8.0 mg/1 is presently unverified, studies should be performed to determine the actual ammonia-nitrogen concentration. Additionally, since the recommended technical subplan for achieving the desired water quality is dependent upon an ammonia-nitrogen concentration of 8.0 mg/1 in the effluent, this value should possibly be incorporated into the discharge permits.

Cypress Creek

Sensitivity analyses for the Cypress Creek drainage basin were performed on benthic demand and channel hydraulics.

1) A lengthy discussion on the benthic demand in Cypress Creek is presented in Chapter III.

2) Channel hydraulic characteristics effect the various rate constants in the stream simulation model. By changing the physical characteristics of the stream in the model, the various constants can be made to enhance water quality (i.e., improving the reaeration constant). It was determined that only minor improvements to the water quality could be obtained through improved stream hydraulics unless the critical segments of the Creek were replaced with a concrete type channel (approximately 10 river miles). Since the adverse environmental impacts of the ten mile channel are significant, utilizing this device to improve dissolved oxygen in Cypress Creek is not appropriate.

Clear Creek

Sensitivity analyses on Clear Creek were performed on the background flow input to the model. The results indicate that even at increases of 20 to 30 times the dry weather background flow, the water quality in the nontidal portion of Clear Creek will not meet the desired water quality without upgrading the point source discharges in the Creek.

Houston Ship Channel

Sensitivity analyses were performed on effluent dissolved oxygen concentration, ammonia-nitrogen concentration, background flow, increasing wasteloads and supplemental aeration. The analyses gave the following results:

1) Setting the effluent dissolved oxygen concentration to 0.0 mg/l at the Northside/69th Street and Sims Bayou treatment plants had virtually no effect on the Houston Ship Channel water quality when compared to the simulation using the assumed dissolved oxygen concentration of 4.0 mg/l. Similarly setting effluent dissolved oxygen concentrations at 6.8 mg/l had virtually no effect on Turning Basin dissolved oxygen.

2) Setting the effluent ammonia-nitrogen concentration of all municipal treatment plants at 20.0 mg/l except for those permitted at level 2N (Northside/69th Street and Sims Bayou), had no major impact (less than 0.2 mg/l) on the water quality of the Houston Ship Channel when compared to the originally assumed ammonia-nitrogen concentration of 8.0 mg/l.

3) Increasing the Buffalo Bayou, Brays Bayou and Sims Bayou tributary flows by 50 percent without altering the total wasteload or dissolved oxygen deficit, produced an increase in the dissolved oxygen concentration in the Turning Basin of approximately 0.4 mg/l. The flow increases utilized were 108 cfs, 52 cfs, and 84 cfs for Buffalo, Brays, and Sims Bayous respectively. A comparison of flows of these magnitudes to flow duration information is presented below:

USGS Station	Location	Low Flow[1]		Increased Flow[3]	
		cfs	%[2]	cfs	%[2]
08073500	Buffalo Bayou near Addicks	2	92	110	30
08075000	Brays Bayou at Houston, Texas	0.83	98	53	25
08075400	Sims Bayou at Houston, Texas	1.83	100	86	6

[1] Two year, seven day low flow utilized as headwater flow.

[2] Percent of time equalled or exceeded.

[3] Low flow plus 108, 52, and 84 for Buffalo, Brays, and Sims respectively.

Therefore, major increased in background flows will be necessary to alleviate the Turning Basin D.O. deficit. Furthermore, any supplemental aeration will have to operate for significant portions of the year.

4) Increasing the wasteloads to the Houston Ship Channel downstream of the San Jacinto River by 400 percent resulted in a decrease in the dissolved oxygen concentration of only 0.1 mg/l at the critical point (Turning Basin). This result appears to be due to the combined effects of tidal dispersion and complete mixing in the bays as assumed in the simulation model.

5) Supplemental aeration is discussed as a control theme in Chapter VII. Based on computer simulation runs, it appears that the effects of major increases in the wasteloads from the San Jacinto River down to Galveston Bay can be offset by minor contributions of oxygen at the Turning Basin.

6) One factor in the sensitivity of the Ship Channel model which could not be investigated is the interface between bayous and the channel. The bayous are not part of the Ship Channel model. They were modeled by a steady state, one dimensional model disregarding dispersion. The output from that modeling process was input to the Ship Channel as a load and flow. It is known that dispersion does

affect those bayous and a more precise modeling effort would involve preparing a unified model for the Ship Channel/bayous complex. However, due to the relative insensitivity of the Ship Channel to loads from these bayous, it is not believed that this will affect major conclusions presented herein.

Postaeration

General

In order to increase the dissolved oxygen level in treated effluents and thereby decrease the oxygen demand on the receiving stream, postaeration of treatment plant effluents has been considered. Through postaeration, the dissolved oxygen level in the treated effluent can be increased to avoid diluting the dissolved oxygen concentration in the receiving stream. As is indicated in previous chapters, postaeration is a major water quality management technique in the Cypress Creek basin.

For the work discussed within, a dissolved oxygen concentration of 6 mg/l was assumed to be the discharge requirement for the treated effluent. Similarly, a chlorine residual of 1.0 mg/l was used as the discharge requirement.

Ozonation

Postaeration may be accomplished simultaneously with disinfection through the use of ozone. Ozone (O_3), an allotropic form of oxygen, is an unstable gas with a characteristic pungent odor, to which it owes its name. Ozone is produced commercially from either dry air or oxygen by the corona discharge of high-voltage electricity. Ozone is an extremely powerful oxidation agent, and only fluorine has a more electronegative oxidation potential. The solubility of ozone in water is a major limiting factor that affects the process of ozonation.

Ozone has been claimed to have twice the oxidizing power of chlorine, and has been investigated for its bacterial, viricidal and cysticidal powers, Below a certain critical concentration, ozone seems to have no disinfecting effect, above this concentration, disinfection seems to be complete. This supports the theory that ozone acts as a protoplasmic oxidant. The aggressive oxidizing capacity of ozone is caused by the breakdown of the third atom of oxygen which is very unstable and reacts quickly with oxidizable matter. In solution, ozone reverts to oxygen,

$$2O_3 \rightarrow 3O_2$$

By this reaction, ozone is able to perform its oxidations, and then revert back to oxygen, thereby increasing the dissolved oxygen concentration.

The major disadvantage of ozonation is the high capital and operating cost associated with its generation. Therefore, the economics for plants with existing chlorination facilities for disinfection to switch to ozonation seem unfavorable. However, ozonation should be included as a alternative in new plant design.

Aeration

Aeration as a means of increasing the treated effluent's dissolved oxygen concentration can be accomplished in any one of three ways:

1) Aeration prior to chlorination,

2) Chlorination followed by aeration,

3) Aeration in the chlorine contact chamber.

Any one of the above strategies would be able to increase the dissolved oxygen concentration in the effluent and will be discussed shortly.

There are four methods currently available for the postaeration of wastewater treatment plant effluent. Most of these devices were originally developed for water treatment but are now being used in the wastewater field. The four methods are:

1) Diffused aeration,

2) Mechanical aeration,

3) Cascade aeration,

4) U-tube aeration.

The design and use of both diffused aeration and mechanical aeration devices is similar to applications in the activated sludge process. Cascade aeration takes advantage of the effluent's available head and maximizes turbulence and mixing through a series of steps or weirs to increase oxygen transfer. Head requirements vary from three to ten feet depending on the initial dissolved oxygen concentration and the desired increase. If the necessary head is not available, pumping is required. The U-tube aerator consists of a conduit to provide a vertical U-shaped flow path and a device for entraining air into the stream flow. The entrained air is entered along the down leg of the tube and is carried along since the water velocity is greater than the buoyant rising velocity of the air bubbles. For plants less than 5 mgd, five foot of head is sufficient. As with the cascade aerator, pumping may be required if the available head is not sufficient.

Aeration Prior to Chlorination

Aeration prior to chlorination would be carried out in an aeration tank upstream of the chlorine contact tank. The aeration tank can be either an empty existing tank or a new tank build specifically for postaeration. Either diffused aeration or mechanical aeration of the tank is feasible, with the choice dependent on the type of aeration used elsewhere in the treatment plant. A detention time of 10 to 30 minutes is typical.

If one is to aerate prior to chlorination, the dissolved oxygen concentration of the aeration tank effluent minus the dissolved oxygen uptake through the chlorination facility must be greater than or equal to 6 mg/l. Following secondary treatment and efficient solids-liquid separation, the biodegradable material remaining in the wastewater should be minimal. In addition, the micro-organisms remaining in the settled effluent is minimal. These two factors in combination point toward a minimal dissolved oxygen uptake rate in the effluent. Furthermore, the addition of chlorine may reduce the residual biological activity.

Chlorination Followed by Aeration

In this scheme, chlorinated effluent would flow from the chlorine contact chamber into a postaeration system. Given enough available head, the cascade or U-tube methods of reaeration seem favorable, as no additional power requirements are necessary. If the available head is not sufficient, then the economics of pumping the effluent prior to U-tube or cascade aeration versus conventional aeration (i.e., mechanical or diffused aeration) should be investigated.

With regard to chlorination followed by postaeration, the question to be investigated involves the "die-off" of chlorine residual as a function of time. The chlorine residual die-off is important since a detention time of 10 to 30 minutes is necessary in the reareation basin. This die-off has been examined by Lin and Evans (1) and found to be described by:

$$D = Kt^n$$

where D is the chlorine demand in mg/l, t is the contact time in minutes, K is the chlorine demand coefficient and n is a constant. Both n and K are functions of the chlorine dosage to ammonia-nitrogen ratio.

For an ammonia-nitrogen effluent value of 15 mg/l and a chlorine dosage of 10 mg/l, using the method of Lin and Evans, the chlorine residual at 30 minutes is 8.3 mg/l compared to 8.1 mg/l after 60 minutes. Similarly for an ammonia-nitrogen value of 15 mg/l and a chlorine dosage of 5 mg/l, the residual chlorine after 30 minutes is 3.5 mg/l as compared to 2.8 mg/l after 60 minutes.

One can conclude that the additional 30 minutes of chlorinated effluent detention time necessary for reareation by a mechanical or diffuse aeration system will not substantially lower the chlorine residual, as the additional chlorine die-off between 30 and 60 minutes detention time is minimal. With regard to the cascade of U-tube aeration systems, the detention times are far shorter, and even smaller chlorine residual losses can be expected.

Aeration in the Chlorine Contact Chamber

The third alternative involves the introduction of the air into the chlorine contact chamber. In this alternative, diffused air is used to reaerate the water prior to discharge. The major question to be answered involves whether the sweeping of the chlorinated water of a contact tank reduces the chlorine residual of the water sufficiently to impair the effectiveness of disinfection. In order to answer this question, a review of the chemistry of chlorination is necessary.

When chlorine gas dissolves in water,

$$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$$

where the hydrolysis constant, $K_H = 4.3 \times 10^{-4}$ at 25°C where

$$K_H = \frac{(H^+)\ (Cl^-)\ (HOCl)}{Cl_2}$$

From this equilibrium, the percent of molecular chlorine and hypochlorous acid present as a function of pH and chlorine concentration can be calculated. Above a pH of 3, and a chlorine concentration of 1,000 mg/l or less, little molecular chlorine exists. The speed of the hydrolysis reaction is extremely quick with the reaction complete in a few tenths of a second at a temperature of 65°F.

Hypochlorous acid is classified as a weak acid and undergoes a partial disassociation,

$$HOCl \rightleftharpoons H^+ + OCL^-$$

to produce a hypochlorite ion and a hydrogen ion. The concentration of hypochlorite ion becomes appreciable above pH 6, in a region where molecular chlorine is non-existant.

The most profound effect on wastewater chlorination practice is associated with ammonia. Chlorine, when added in the presence of ammonia forms chloramines,

$$NH_3 \longrightarrow NH_2Cl \longrightarrow NHCl_2 \longrightarrow NCl_3$$

Ammonia	Monochloramine	Dichloramine	Trichloramine or Nitrogen Trichloride

In general, the lower the pH and the higher the chlorine to ammonia ratio, the greater the tendency to produce chlorinated derivatives. Also, the rate of reaction becomes slower with greater substitution of chlorine.

Providing that the chlorine dose does not exceed 5 times the ammonia-nitrogen in the water, all chlorine will go toward producing stable monochloramine in the neutral and alkaline pH range. Above this 5:1 range, the ammonia is converted to nitrogen gas (N_2) with some formation of dichloramine and trichloramine. The final overall equation is:

$$2NH_3 + 3Cl_2 \rightarrow N_2 + 6HCl$$

By this reaction, 7.6 parts of chlorine are required to oxidize 1 part by weight of ammonia-nitrogen. In practice, this ratio approaches 10:1.

The major reason for discussing the formation of chloramines is that dichloramine and nitrogen trichloride are believed to be volatile. Therefore, during the aeration of chloramine containing wastewater, some loss of combined chlorine is possible. As there is an equilibrium between the chloramines,

$$2NH_2Cl + H^+ \rightleftharpoons NH_4^+ + NHCl_2$$

the volatilization of dichloramine will shift the reaction to the right and cause the production of dichloramine to replace the volatized dichloramine.

In bench and actual scale testing of chlorine contact chamber aeration by Kappe (2), Kothandaraman and Lin (3), positive results were obtained. In these studies, it was found that aeration of chlorinated wastewater did not reduce chlorine residuals. In fact, in an actual plant installation residual chlorine levels actually increased. This increase was due to the increased mixing level in the tank which prevented the deposition of suspended solids and the subsequent chlorine demand of the products of anaerobic decomposition.

The present survival of bacteria in the aerated versus the nonaerated system has also been investigated. The results indicated that there was no significant difference in bacterial survival in the aerated versus nonaerated system for most cases, and in a few cases, an increase in die-off was reported.

A decrease in the residual combined chlorine is not expected due to chloramine volatilization as a chloramine to ammonia-nitrogen ratio of greater than 5:1 is necessary to form dichloramine and nigrogen trichloride, the two volatile chloramines. Assuming an 8.0 mg/l concentration of ammonia-nitrogen, this would mean a chlorine dosage of 40 mg/l or more than the typical dosage. In the case of nitrified or denitrified effluents, the ammonia-nigrogen concentration may be extremely low, and the chlorine to ammonia-nitrogen ratio may be greater than 5:1.

It should be stated that aeration in the chlorine contact chamber should be designed so that aeration occurs toward the tail end of the tank. In this way, more than sufficient time will be allowed for Cl_2 hydrolysis. As a typical chlorine tank detention time is 30 minutes, one can for example provide 10 minutes for hydrolysis and 20 minutes for aeration.

Temperature Effects

Wastewater temperatures in the range of 80^o - 90^oF do not generally affect the kinetics described for postaeration and chlorination. The disassociation rate of chlorine gas in water is reduced at increased temperatures. However, since high concentrations of chlorine gas are utilized, this does not affect the chlorination process. The reaction most greatly affected by the high wastewater temperatures typified in the 208 planning area is the formation of dichloramines and trichloramines from monochloramines. This reaction rate is inhibited at increased temperatures. Since it is the dichloramines and trichloramines that are the most volatile components of residual chlorine, the higher temperatures found in the 208 planning area actually inhibit the stripping of residual chlorine due to postaeration performed in the chlorine contact chamber.

Based on the previous discussion, the following conclusions and recommendations are presented:

1) Ozone is an effective means of disinfecting effluent waters and producing a high residual dissolved oxygen concentration.

2) Postaeration can be applied either prior to, after, or in conjunction with chlorination.

3) Aeration in the chlorine contact tank should not cause a significant decrease in the effluent's residual chlorine concentration.

4) Ozone be investigated as a means of disinfection and reaeration in new treatment facilities.

5) Cascade and U-tube aerators due to their negligible power consumption, be installed where sufficient head exists.

6) Where sufficient head does not exist, aeration in the chlorine contact chamber would seem to be the most cost-effective solution, unless empty existing tanks are present.

7) Wastewater temperatures typically found in the 208 planning area do not create any problems or adverse affects for the kinetics related to the postaeration process as described herein.

Wastewater Disinfection

General

The primary objective of wastewater disinfection, as reported by the EPA, is to protect the public health from the spread of disease by controlling the point source discharge of pathogenic microorganisms and viruses. The disinfection process should not be inherently toxic to the receiving water flora and fauna. Furthermore, the formation of by-products potentially toxigenic to man must be minimized.

On July 26, 1976, the EPA officially deleted the fecal coliform standard from the Secondary Treatment Information Regulation (40 CFR 133) defining secondary treatment as mandated in Public Law 92-500. Reliance on the site-specific water quality standard of each state to set disinfection requirements for municipal wastewater treatment plants shall now be the practice. Thus, disinfection will still be required by state regulation, but no uniform Federal requirement has to be achieved.

Chlorine

Chlorination is practiced widely, but too often the practices are careless, wasteful, and inadequate. Recently, chlorine has been identified as being toxic to certain aquatic species at very low concentrations. Furthermore, chlorine has been implicated as a major contributing factor to the formation of compounds potentially carcinogenic to man. Nevertheless, it is a cost-effective disinfectant, and fairly precise methods of continuous feedback control are available.

A major concern expressed by the Citizens Advisory Group is the high level of residual chlorine in many of the sewage treatment plant effluents, especially in the Spring Creek and Cypress Creek watersheds. Although no specific studies have been performed in the Spring/Cypress basin to determine the reason for the high chlorine residuals, one possible explanation is that most of the treatment plants in the area do not have a full time operator. Therefore, chlorine dosages are pre-set at a continuous feed rate to provide a residual at a peak flow rate which may occur only a small percentage of the time. The remainder of the time, the constant chlorine feed rate produces an excess residual level in the effluent. The most pressing need in chlorine development technology for the 208 area is optimization of control to achieve the desired bacteriological effect and minimum residual discharge

Control of Chlorine Residuals

Excessive chlorine residuals can be reduced through better controls in the chlorine feed systems or if necessary through dechlorination with sulfur dioxide.

Assuming existing flow monitoring which produces a feedback signal of 4 to 20 milliamps and existing chlorination facilities, an automatically paced chlorinator can be installed for approximately $6,000 for plant sizes up to approximately 2 MGD. Utilizing a 1 MGD flow and assuming a chlorine dosage savings of 2 mg/l and 16¢/lb. cost of chlorine, chemical savings would amount to approximately $1,000 annually, or a six year pay back period. The pay back period would be even shorter in the case of a new plant, where only the incremental cost between paced and non-paced chlorinators is involved.

Additionally, alternatives to chlorine disinfection are available such as ozone as discussed previously.

Therefore, the following conclusions and recommendations are presented:

1) Based on the information available, it is questionable whether it is preferable to discharge unchlorinated effluent or effluent with an excessive chlorine residual.

2) As previously cited, ozone should be investigated as an alternative for chlorine in new treatment facilities.

3) The State should initiate an investigation into the feasibility of incorporating a maximum as well as a minimum residual chlorine concentration in applicable discharge permits. This maximum level should be as close to the minimum level as possible given the existing level of technology.

4) The State should consider waving minimum chlorine residuals in areas where chlorine has a deleterious effect on the receiving water course.

Suspended Solids from Nonpoint Sources

General

Suspended solids entering the stream segments from nonpoint sources in the 208 area have been identified in the Nonpoint Source Analysis. These loads are summarized and presented below in Table VII-1.

As seen in Table VII-1, urban runoff accounts for approximately 64 percent of the total nonpoint source load, construction activities account for approximately 32 percent, and the remainder is derived from agricultural activities.

TABLE VII-1

SUMMARY OF ANNUAL SUSPENDED SOLIDS LOADING
(Tons per Year)

Year	Urban	Agricultural	Construction	Total
1975	726,000	60,000	440,000	1,226,000
1983	799,000	59,000	382,000	1,240,000
1990	884,000	58,000	426,000	1,368,000
1995	924,000	57,000	426,000	1,407,000

Although the total annual suspended solids loading from nonpoint sources is estimated to be greater than 1,000 times the suspended solids from municipal point sources, there is no information available to assess the significance or impact of these loads. Part of the reason for the apparent lack of information is due to the fact that these wasteloads are mostly stormwater related. The concentrations and runoff rates will vary with the storm intensity and, therefore, it is extremely difficult to relate the loadings to water quality.

Impacts of Suspended Solids

There are minimal data available documenting water quality impact due to suspended solids loading from nonpoint sources. The following are potential impacts:

1. Contribution to BOD loading. This potential impact has been covered under the wet weather technical subplans developed in Chapters III-VI.

2. Contribution to benthic demand. Some streams in the area, primarily Cypress Creek, have benthic demand rates which are significant sinks of dissolved oxygen. It is likely that these benthic demands are resultant from a combination of point and nonpoint source suspended solids which have been depositied on the stream bottom.

3. Suspended solids in surface waters. This potential impact is likely short term in nature.

4. Siltation of streams and reservoirs. This impact cannot be rigorously assessed in streams, since siltation is a

> combination of deposition and scarification and no models have been developed to assess this phenomona in area streams. With respect to reservoirs, silt could be significant. Tributaries to Lake Houston have total nonpoint source suspended solid loadings in excess of 200,000 tons/year from within the study area. Assuming that all these solids are deposited in the Lake at an ultimate solids concentration of 50 percent and a density of 150 lbs./cu.ft., this is a solids accumulation rate of more than 115 acre ft./year. This number compares to 6,180 acre feet of storage at the lowest gated outlet. Thus, these suspended solids from nonpoint sources are a major cause of siltation in Lake Houston.

The more obvious impacts of suspended solids from nonpoint sources are not areawide water quality impacts. Specifically,

1. Erosion at the site itself,
2. Localized water quality impacts,
3. Localized flooding due to rapid runoff from eroded lands.

Urban Areas

Urban runoff is the major contributor to annual suspended solids loading. It is also the most constant and predictable source of nonpoint suspended solids. However, the heaviest wasteloads predicted result from the most concentrated areas or urban development which are the most difficult areas to apply any type of low cost nonstructural control technique.

The oxygen demanding materials impact is discussed in Chapters III-VI.

With respect to suspended solids in surface waters, this impact is probably short term in nature and difficult to quantify. Therefore, no controls are appropriate for this impact.

With respect to siltation, while this impact may be significant for Lake Houston, its control is more appropriately based on a siltation study of that lake than data presented herein.

Construction Activity

Of the potential impacts of suspended solids discussed previously, those most associated with construction activities are: suspended solids in receiving waters, siltation, erosion and localized flooding.

While construction activity suspended solids account for only about one-half of the urban suspended solids loads, the impact of construction activity is more severe because:

1) The construction activities producing the load include a much smaller land area than do the urban activities. Thus, the suspended solids are washed off a smaller area and, therefore, the erosion is much more significant.

2) Due to the localized nature of construction activities, the suspended solids resultant from runoff from these activities are input to water courses in a concentrated form in fewer locations than is the urban runoff. Thus, localized water quality problems are more likely to result.

Due to reasons cited for urban areas, controls for limiting suspended solids for construction related activities cannot be recommended based on specific predictions of water quality problems. However, there are good reasons to require some type of erosion control beyond water quality considerations. Among these are the following:

1) To prevent soil losses from construction sites,

2) To prevent local nuisance conditions,

3) To protect against localized flooding due to rapid runoff.

Since each construction site has unique qualities which require individual attention, no recommendation can be made on an areawide basis for specific control implementation.

Agricultural Area

Controls on agricultural runoff will not significantly reduce the total annual loads to the stream since these loads have been identified as making up less than 5 percent of the total suspended solid wasteload contribution. Additionally, controls on agricultural runoff would impact a disproportionate share of the cost to a small section of the community.

The main advantage for agricultural runoff controls is to protect against soil erosion and the loss of fertile lands during major storm events. Modern farming and water management techniques developed through Soil Conservation Services and Agricultural Extension Services provide the best and most logically implemented techniques for reducing erosion.

Infiltration/Inflow

Infiltration/Inflow is generally defined as extraneous waters entering a sewer system which reduce the capability of the system to transport and treat domestic and industrial wastewaters. Infiltration/Inflow is differentiated by source: Infiltration from the ground through such means as defective pipes, pipe joints, connections, or manhole walls, and inflow from such above ground sources as roof leaders, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catch basins, storm waters, surface runoff, street wash water, or drainage.

Detrimental effects of infiltration/inflow, in addition to the reduction in the capacity of the collection and treatment system, include pipe and road damage attributable to a combination of infiltration-exfiltration and resulting washout of soil bedding; surcharged sewers preventing the use of plumbing facilities; increased sewerage system operating costs; and the health hazards and water quality problems resulting from bypasses and overflows of raw sewage or inadequately treated wastewaters.

Since there has not been any information gathered for the 208 area program relative to the extent of infiltration/inflow presently existing, no definitive statements for controls can be proposed. However, the technology does exist for monitoring and rehabilitating sources of infiltration/inflow and the economics and potential savings often justify local control programs.

Municipal Sludge Disposal

The Sludge and Residual Waste Inventory reported the results of a questionaire mailed out to 257 municipal sewage treatment plants. The results indicate that approximately 73 percent of the plants responding to the survey disposed of their residual sludge on-site as fill material or that area citizens utilized it. The average daily flow of these plants with on-site disposal was 0.465 MGD with the largest single plant flow approximately 2.8 MGD.

The City of Houston incorporates sludge transfer facilities at their smaller treatment plants and has constructed or planned for sludge processing facilities at their larger regional plants. The City of Houston sludge disposal process involves gravity thickening, dewatering on vacuum filters, and flash drying for subsequent sale as commercial fertilizer. The scheme leaves no residue for ultimate disposal.

The remainder of the municipal treatment plants rely on off-site disposal such as existing land fills or private land. There is presently not enough information available to determine the total amount of residual waste sludge requiring off-site disposal within the 208 planning area.

Part of the reason for the relatively small number of plants that require off-site disposal of residual sludge is due to poor operation and maintenance of existing facilities and the fact that many existing treatment plants are not operating in an acceptable manner. Some plants are reported to never draw sludge, this obviously being the result of constant loss of solids to the effluent. Others pile dried sludge at the plant site, with ultimate disposal being left to unformalized usage by area farmers, landowners, etc. Such practice is unsatisfactory because of the probability that leachate and runoff from the sludge pile will reach area watercourses. In order to avoid these situations:

1) Permits solids requirements must be enforced.

2) On site storage areas must be diked with provisions for returning polluted waters to the treatment system.

3) Definitive provisions for sludge disposal must be made.

The Sludge and Residual Waste Inventory report estimates that 1,100 pounds of dry sludge are generated per million gallons of wastewater flow. If approximately 25 percent of the future municipal wastewater flow projected in the Point Source Analysis Report (375 MGD) requires residual off-site sludge disposal, a total of approximately 50 tons per dav of dry solids will be produced. Based on an ultimate average sludge moisture content of 70 percent following sludge drying or vacuum filtration, it is estimated that 5,500 cubic feet of sludge will require off-site disposal per day. This figure is approximately one percent of the volume required for domestic refuse in the planning area.

There are three logical disposal alternatives for the projected sludge volume, existing landfill/disposal sites as identified in the Solid Waste Site Survey report, new or future landfill/disposal sites, and existing crop or farm lands available in the area. Dried, digested sludge may be disposed of in a Type I sanitary landfill as permitted by the Texas State Department of Health. Landfills accepting sewage sludge should be required to have daily coverage, control of polluted runoff, and be located where they do not pose hazards to aquifers or surface water. It is recommended that municipal waste sludges be applied to farm and crop lands whenever possible in order to take advantage of the inherent value of the sludge as a nutrient source and a soil conditioner.

REFERENCES

(1) Lin, S. D., and Evans, R. L., "Chlorine Demand Study of Secondary Sewage Effluents", Water and Sewage Works, January 1974.

(2) Kappe, D. S., "Aeration in Chlorine Contact Tanks", Kappe Associates, Inc.

(3) Kothandaraman, V., and Lin, S. D., "Air Agitation of Treatment Plant Effluents", Public Works, August 1973.

CHAPTER VIII - SUMMARY OF PREFERRED PLAN

CHAPTER VIII - SUMMARY OF PREFERRED PLAN

General

Chapters I through VII present the base information, methodology and assumptions, alternative technical subplans, and other items of importance utilized in the development and selection of a preferred technical plan. The selection process included inputs from the H-GAC staff, the Technical Advisory Committee, the Citizens Advisory Group, and the Areawide Planning Advisory Committee.

Based on the cumulative inputs, a preferred plan has been selected from the alternative technical subplans presented in Chapters III through VI and the general areawide considerations presented in Chapter VII. This chapter is designed to summarize the preferred plan and its effects on the future water quality of the area on a basin by basin analysis.

Spring Creek

The preferred alternative technical subplan for Spring Creek is to maintain the permitted level of control presently existing in the basin. This plan was selected because it is projected to meet or exceed the goal of fishable/swimmable streams if all existing and future dischargers achieve their permit requirements. Additionally, the plan does not specifically require control of nonpoint source wasteloads. Control of nonpoint source suspended solids should be considered for reasons other than resultant water quality as detailed in Chapter VII.

Although there are indications that some level of regionalized sewage treatment may provide financial incentives (i.e., economy of scale, etc.), the nonregional concept is recommended as part of the preferred plan. The major obstacles to a regionalized system are the rapid development of the area combined with the lack of an overall management system to fully develop, operate, and control a regionalized sewage treatment system. The management system developed as part of the 208 program will, in time, be able to respond to the needs and economics of a regionalized treatment system. Until such time as the management system is fully operable, the nonregional concept is preferable.

Specific portions of the preferred plan are as follows:

Segment: 1008
Water Quality Level Achieved: III
Technical Plan:

1) Continue operation of existing and future municipal point source dischargers at their existing permitted levels.

2) Continue nonregional municipal sewage treatment except as dictated by 201 facility plans or other detailed planning studies.

3) Municipal dischargers existing: 11
   Municipal dischargers projected: 32.

4) Nonpoint source wasteload controls are not required for reasons of water quality. However, specific controls for suspended solids may be implemented for other reasons such as localized flooding and erosion on a case by case basis.

5) A monitoring program should be instituted to continually update and verify the steady-state and non-steady-state water quality simulation models.

6) Consider placing a maximum chlorine residual concentration on wastewater discharges.

7) Consider placing a maximum ammonia-nitrogen limitation on wastewater discharges.

Based on the preferred plan, Table VIII-1 presents a list of the municipal treatment systems projected for Spring Creek. Geographical planning areas are presented in Exhibit III-2.

TABLE VIII-1
PROJECTED MUNICIPAL TREATMENT SYSTEMS
SPRING CREEK

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
SC-1	0	2	0.20	2
SC-2	0	1	0.20	2
SC-3	0	3	1.00	2
SC-4	1	2	0.51	2
SC-5	0	1	0.06	2
SC-6	0	1	0.05	2
SC-7	1	1	0.07	2
SC-8	0	1	0.06	2
SC-9	1	3	0.60	2
SC-10	1	1	0.43	2
SC-11	1	1	0.03	2
SC-12	1	4	2.13	2
SC-13	2	3	2.00	2
SC-14	1	3	0.76	2
SC-15	1	2	0.18	2
SC-16	1	3	0.23	2
TOTAL	11	32	8.51	

The preferred plan in the Spring Creek drainage basin is designed to improve and protect the water quality and thereby enhance the surrounding environment. Incorporation of the Spring Creek plan will not only provide for fishable/swimmable water quality, but will allow for the establishment of a firm and reliable data base for input into the future planning requirements of this rapidly developing area.

Cypress Creek

The preferred alternative technical subplan for Cypress Creek includes several action items. All existing point source dischargers not presently meeting the 2N permitted level of treatment must be upgraded. During the period of treatment plant upgrading, detailed studies of Cypress Creek should be initiated to fully verify the steady-state water quality simulation model with special emphasis on the level and sources of benthal oxygen demand and nitrogenous oxygen demand.

If the results of the verification study indicate that the benthal related oxygen demand can be reduced approximately 65 percent, the desired water quality for Cypress Creek, defined by Water Quality Level III, can be achieved through further upgrading of point source dischargers. If the existing benthal oxygen demand cannot be substantially reduced, the desired water quality level in the Creek cannot be achieved and should be redefined for the segment.

Nonpoint source wasteloads, with the exception of benthic oxygen demand, do not require controls for reasons specifically relating to water quality. Control of nonpoint source suspended solids should be considered for other reasons as detailed in Chapter VII.

There are definite indications that some level of regionalized sewage treatment would provide financial incentives to the residents of the area. The large number of existing (27) and projected (49) sewage treatment plants in the basin, most of which will require some form of advanced wastewater treatment, point out the need and potential savings for well managed regional systems. However, until the proposed management system becomes an active force in the implementation portion of the 208 program, the nonregional concept is the only viable alternative for future planning.

Specific portions of the preferred plan are as follows:

Segment: 1009
Water Quality Level Achieved: I or III
Technical Plan:

1) Continue operation of existing municipal point source dischargers and upgrade where necessary to meet the existing permitted level of 2N.

2) All new municipal treatment plants should be constructed for operation at the existing permitted discharge level but be designed so they can be readily upgraded to treatment level 4N with post-aeration prior to discharge.

3) Initiate studies to update and verify the steady-state and nonsteady-state water quality simulation models.

4) Initiate studies on the benthic demand in the Creek to verify the values utilized and the sources of this oxygen demand.

5) If the results of the studies identified in Number 4 indicate that the benthic demand can be reduced approximately 65 percent, all municipal treatment plants projected or existing will require upgrading to effluent set 4N with postaeration. Offstream dischargers may take credit for any degradation prior to entering Cypress Creek.

6) Cypress Creek may continue with nonregional municipal treatment or may go to a semi-regional system where economic incentive exists.

7) Nonpoint source wasteload controls (except for benthic demand) are not required. However, specific controls for nonpoint source suspended solids may be advantageous to reduce local erosion and its related problems.

8) Consider placing maximum chlorine residual levels in discharge permits.

Based on the preferred plan, Table VIII-2 presents a list of the municipal treatment systems projected for Cypress Creek. Geographical planning areas are shown in Exhibit III-2.

TABLE VIII-2
PROJECTED MUNICIPAL TREATMENT SYSTEMS
CYPRESS CREEK

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
CY-1	1	2	0.27	4NA
CY-2	0	1	0.08	4NA
CY-3	1	2	0.30	4NA
CY-4	0	3	0.30	4NA
CY-5	0	2	0.25	4NA
CY-6	2	3	0.85	4NA
CY-7	1	1	0.45	4NA
CY-8	3	4	1.17	4NA
CY-9	1	1	0.31	4NA
CY-10	3	5	1.73	4NA
CY-11	3	3	0.28	4NA
CY-12	1	1	0.44	4NA
CY-13	0	2	0.36	4NA
CY-14	3	5	2.54	4NA
CY-15	3	6	1.27	4NA
CY-16	2	3	0.57	4NA
CY-17	2	4	0.49	4NA
CY-18	1	1	0.45	4NA
TOTAL	27	49	12.11	

The preferred plan in Cypress Creek requires point source dischargers to produce a high quality effluent. This is due to the rapidly expanding population in the area utilizing the limited wasteload capacity of the Creek.

However, natural sources of oxygen demanding materials impact on the stream quality and, therefore, before requiring upgrading beyond the existing permit level, further studies are required. These studies will better determine the attainable water quality goals in Cypress Creek.

Phase one of the preferred plan, upgrade treatment plants to existing permitted levels and initiate further water quality studies, coupled with phase two, re-assess the existing water quality and projected goals, combine to form a solid basis for obtaining the overall objectives of the 208 program. The Cypress Creek basin is the most complex of the entire 208 Planning Area and, therefore, a cautious and phased approach based on verified data is required to successfully implement the water quality management program.

Lake Houston

The preferred alternative technical subplan for the Lake Houston drainage basin is to maintain the permitted level of control presently existing in the basin. This plan was selected because it is projected to maintain the high level of water quality currently predicted for Lake Houston, based on point source dischargers meeting their existing permit levels.

The plan does not specifically recommend controls on nonpoint source wasteloads. However, controls for localized nonpoint sources of suspended solids should be considered for reasons not directly related to water quality as discussed in Chapter VII.

Additionally, continuous studies of the lake are required. Lake Houston is a water supply and a major recreational attraction in the planning area. The monitoring program should be designed to assess the fishable/swimmable water quality and to accurately determine the various sources and potential for eutrophication.

The nonregional concept of municipal sewage treatment is recommended since there appears to be little incentive for a regional system at this time. However, any future 201 facility plans should fully assess the advantages and economics of a regionalized system.

Specific portions of the preferred plan are as follows:

Segment: 1002
Water Quality Level Achieved: III
Technical Plan:

1) Continue operation of existing and future municipal point source dischargers at their existing permitted levels.

2) Continue nonregional municipal sewage treatment except where dictated by 201 facility plans or other

detailed planning studies.

3) Institute continuous monitoring of the Lake to fully assess the various sources and potential for eutrophication.

4) Nonpoint source wasteload controls are not required for reasons of water quality. However, specific controls for suspended solids may be implemented on a case by case basis to prevent localized flooding, erosion, and general nuisance conditions.

Based on the preferred plan, Table VIII-3 presents a list of the municipal treatment systems projected for the Lake Houston segment. Geographical planning areas are presented in Exhibit III-2.

TABLE VIII-3
PROJECTED MUNICIPAL TREATMENT SYSTEMS
LAKE HOUSTON

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
LH-1	1	2	0.67	2
LH-2	5	8	3.50	2
TOTAL	6	10	4.17	

The preferred plan for Lake Houston is designed to protect the presently existing high water quality. The plan requires a thorough examination of the Lake's ecosystem in order to retard or inhibit eutrophication. The plan presents a logical approach for safeguarding the many uses of Lake Houston.

Clear Creek - Nontidal

The preferred alternative technical subplan for the nontidal portion of Clear Creek requires control of both point source and nonpoint source wasteloads, combined with a change in the desired water quality criteria presently defined for the Creek. Additional point source controls are required due to the relatively large amount of oxygen demanding material entering the Creek during low flow conditions. Nonpoint source controls are required to protect the Creek from rapidly increasing amounts of urban runoff projected for the area over the planning period.

A change in the permitted effluent set from 3NP to 4NP with postaeration prior to discharge will upgrade the level of sewage treatment for oxygen demanding materials. However, based on the water quality simulation model, the upgrading of the point source dischargers will not achieve the desired criteria throughout the Creek. Therefore, the dissolved oxygen concentration for Water Quality Level III should be lowered to 4.5 mg/l. This change will not greatly affect the overall fishable/swimmable quality of the Creek.

The control program for reducing the nonpoint source wasteloads resulting from urban runoff is based on testing and implementation of nonstructural strategies and land use policies. The nonstructural controls are to be implemented on presently vacant land and in flood plain areas in the vicinity of existing urban development. New subdivisions should design nonstructural control techniques into their overall plans.

There are definite indications that some level of regionalized sewage treatment will be beneficial to the area's residents, as exhibited by existing 201 facility plans in the basin. However, until the proposed management system becomes implemented, the nonregional concept is recommended except where existing 201 facility plans dictate regional systems.

Specific portions of the preferred plan are as follows:

Segment: 1102
Water Quality Level Achieved: III
Technical Plan:

1) Change the desired D.O. concentration defined by Water Quality Level III from 5.0 mg/l to 4.5 mg/l. This will not affect the overall fishable/swimmable quality of the Creek.

2) Upgrade all existing municipal treatment plants to produce effluent set 4N with postaeration.

3) All future plants must be operated at effluent set 4N with postaeration.

4) Consider elimination of the phosphorus control requirement based on the recommended eutrophication study of Clear Lake.

5) Continue nonregional municipal wastewater treatment except where dictated by 201 facility plans or other planning studies.

6) Nonpoint source wasteloads are projected to present

a water quality problem and, therefore, controls are required. The nonpoint source control strategies are based on a testing and implementation program of nonstructural controls. Additionally, future implementation of the nonstructural controls requires that existing land areas be reserved to be utilized in the control program.

7) Specific controls for nonpoint source suspended solids may be advantageous to reduce local erosion and its related problems.

8) Monitoring should be performed to verify the accuracy of the steady-state and nonsteady-state water quality simulation models.

9) Maximum limits on chlorine residuals from wastewater treatment systems should be considered.

Based on the preferred plan, Table VIII-4 presents a list of the municipal treatment systems projected for the nontidal portion of Clear Creek. Geographical planning areas are shown in Exhibit IV-2.

TABLE VIII-4
PROJECTED MUNICIPAL TREATMENT SYSTEMS
CLEAR CREEK - NONTIDAL

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
CL-1	3	7	3.50	4NA
CL-2	3	3	7.30	4NA
CL-3	3	0	-	-
TOTAL	9	10	10.80	

The preferred plan in the nontidal portion of Clear Creek requires point source dischargers to produce extremely high quality effluent. Additionally, the plan requires immediate action to initiate the management system for control of the potential nonpoint source problems in the area.

A technically feasible alternative to the point source controls of the preferred plan described above is to utilize interbasin transport of effluent from the Clear Creek basin into the Sims Bayou drainage basin. This alternative technical subplan is detailed in Chapter IV.

The major reason that this alternative was not selected as the preferred plan is due to the inability to totally assess the economics and social/political sensitivity of the plan. However, prior to requiring any upgrading of existing treatment systems, a detailed evaluation of this alternative and its impacts is recommended.

Through these combined actions, the water quality of Clear Creek can be protected from the effects of rapid development and urban growth. Of particular importance is the rapid implementation of the nonpoint source wasteload control program before available land areas become fully developed. Once this occurs, only the very expensive structural controls will be available to protect the water quality.

Clear Creek - Tidal

The preferred alternative technical subplan for the tidal portion of Clear Creek is to maintain the existing permitted level of control on oxygen demanding parameters and drop the existing requirement for removal of phosphorus from point source dischargers. This plan was selected because it is projected to meet or exceed the goal of fishable/swimmable streams if all existing and future point source dischargers achieve their permit requirements.

No specific controls are recommended for nonpoint source storm water related wasteloads because a water quality simulation model is not available for the tidal portion of Clear Creek. However, storm water related wasteloads similar to those projected for the nontidal portion may occur and, therefore, require actions to reserve land for future implementation of nonstructural controls. Controls for nonpoint source suspended solids may be advantageous from an aspect other than water quality, as detailed in Chapter VII.

There are indications that some level of regionalization may be beneficial to the area's residents, as exhibited by existing 201 facility plans in the basin. However, until the proposed management system is implemented, the nonregional concept is preferable except where existing 201 facility plans dictate regional systems.

Specific portions of the preferred plan are as follows:

Segment: 1101
Water Quality Level Achieved: III
Technical Plan:

1) Continue operating all existing and future municipal treatment plants at the existing permitted level.

2) Consider elimination of the phosphorus requirement based on the results of the recommended Clear Lake eutrophication study.

3) Continue nonregional municipal wastewater treatment except as dictated by existing 201 facility plans or other detailed planning studies.

4) Since no stormwater modeling is available for Clear Creek - Tidal, nonpoint source controls have not been developed. However, a monitoring program is recommended to determine if wet weather water quality for the tidal section of Clear Creek parallels that predicted in the nontidal portion. If results of monitoring indicate a potential wet weather related water quality problem, controls similar to those proposed in the nontidal portion are recommended.

5) Maximum limits on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Based on the preferred plan, Table VIII-5 presents a list of the municipal treatment systems projected for the basin. Geographical planning areas are presented in Exhibit IV-2.

TABLE VIII-5
PROJECTED MUNICIPAL TREATMENT SYSTEMS
CLEAR CREEK - TIDAL

Geographical Planning Area	Number Existing	Number Projected	Flow (MGD) Projected	Level of Treatment
CL-4	2	1	3.25	3N
CL-5	3	3	1.08	3N
CL-6	2	2	1.57	
TOTAL	7	6	5.90	

The preferred plan in the tidal portion of Clear Creek is designed to maintain the social/recreational aspects of the greater Clear Creek area. Continuation of the existing controls will provide the residents of the area with fishable/swimmable water quality throughout the planning period.

Clear Lake

The preferred alternative technical subplan for Clear Lake is to continue the presently existing level of control for oxygen demanding parameters in the basin. This plan was selected because it was projected to maintain the fishable/swimmable water quality desired in Clear Lake if all existing and future dischargers achieve the permitted levels. Additionally, the plan does not specifically require control of nonpoint source wasteloads to maintain water quality. Control of nonpoint source suspended solids should be considered for reasons other than resultant water quality, as detailed in Chapter VII.

Nonregional sewage treatment systems are recommended due to the small number of systems projected in the basin. However, where detailed planning indicates that incentives exist for regional systems, the regional system should take precedence.

Specific portions of the preferred plan are as follows:

Segment: 2425
Water Quality Level Achieved: III
Technical Plan:

1) Continue operating all existing and future municipal treatment plants at the existing permitted level.

2) Consider elimination of the phosphorus removal requirement based on the recommended eutrophication study of Clear Lake.

3) Continue nonregional municipal wastewater treatment except where detailed planning studies dictate regional systems.

4) Municipal dischargers existing: 4
   Municipal dischargers projected: 4

5) Stormwater modeling is not available for Clear Lake. Therefore, specific nonpoint source controls have not been recommended. A monitoring program similar to that described for the Clear Creek tidal portion is recommended.

6) Nonpoint source controls for suspended solids may be implemented for specific localized situations to prevent soil erosion and related nuisance conditions.

7) Maximum chlorine residual levels from wastewater treatment plants should be considered.

Based on the preferred plan, Table VIII-6 presents a list of the municipal treatment systems projected for the Clear Lake basin. Geographical planning areas are presented in Exhibit IV-2.

TABLE VIII-6
PROJECTED MUNICIPAL TREATMENT SYSTEMS
CLEAR LAKE

Geogrpahical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
CL-7	4	4	1.01	3N

The preferred plan in the Clear Lake basin is designed to protect the water quality and enhance the environment of the area. Implementation of the preferred plan will provide for fishable/swimmable water quality at a lower sewage treatment cost due to the elimination of phosphorus controls.

Armand Bayou

The preferred plan for Armand Bayou is to continue the existing level of permitted discharge, except for phosphorus restrictions, to the bayou. This alternative is not projected to produce the water quality desired for the basin as defined by Water Quality Level III. The plan will achieve Water Quality Level II.

Armand Bayou is an unclassified water segment and, therefore, no definitive water quality modeling has been performed to simulate the segment during cirtical flow conditions. The general water quality simulation model utilized for the bayou predicts that Water Quality Level III cannot be achieved unless significant portions of the wasteload are entirely removed from the basin. Therefore, prior to recommending controls with major impacts, such as interbasin transport of treated wastewater, a detailed analysis of the bayou is recommended in order to obtain the specific information necessary to develop a water quality simulation model of the segment. Based on the results of detailed water quality simulations during critical flow conditions, realistic goals can be set for the bayou. Until this occurs the existing level of control should be maintained.

Specific portions of the preferred plan are as follows:

Segment: Unclassified
Water Quality Level Achieved: II

Technical Plan:

1) Continue operating all existing and future municipal treatment plants at the existing permitted level.

2) Consider elimination of the phosphorous requirement based on the results of the recommended Clear Lake eutrophication study.

3) Continue nonregional municipal wastewater treatment.

4) Municipal dischargers existing: 3
   Municipal dischargers projected: 4

5) Detailed modeling is not available for Armand Bayou. A program should be implemented to develop detailed information and realistic goals for the segment.

Based on the preferred plan, Table VIII-7 presents a list of the municipal treatment systems projected for Armand Bayou. Geographical planning areas are presented in Exhibit IV-2.

TABLE VIII-7

PROJECTED MUNICIPAL TREATMENT SYSTEMS
ARMAND BAYOU

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
AB-1	1	1	4.62	3N
AB-2	0	0	0	-
AB-3	2	3	2.13	3N
TOTAL	3	4	6.75	

The Armand Bayou preferred plan is based on the concept that further information must be developed to accurately determine the needs of the area. The existing permitted level of point source dischargers already requires a high quality effluent to be produced. Therefore, the first phase of any long term water quality plan for the area should be to upgrade the existing facilities to their presently required level and then assess the situation. This approach will provide for a logical and realistic water quality goal to be developed in the area.

Dickinson Bayou

The preferred plan in the Dickinson Bayou drainage basin is to maintain the existing level of control. This plan is projected to nearly achieve Water Quality Level III in the nontidal portion of the bayou and Water Quality Level II in the tidal portion. This plan was selected based on the limited information and nonspecific simulation modeling available for critical dry weather conditions.

No controls are recommended for nonpoint source stormwater related wasteload. Although stormwater modeling was not available for Dickinson Bayou, due to the low concentration of urban development projected, it is not anticipated that stormwater runoff will present major water quality problems, although several completed studies show elevated fecal coliform levels resulting from stormwater runoff (TDWR Report No. WQS-24).

Specific portions of the preferred plan are as follows:

Segment: 1104 (nontidal)
Water Quality Level Achieved: III
Technical Plan:

1) Continue operating the existing municipal treatment system at the existing permitted effluent set.

2) No stormwater modeling is available for Dickinson Bayou. Therefore, nonpoint source controls have not been developed. A monitoring program similar to that described for the tidal portion of Clear Creek is recommended.

3) A monitoring program should be instituted to develop steady-state and nonsteady-state water quality simulation models for the segment.

4) Maximum limites on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Segment: 1103 (tidal)
Water Quality Level Achieved: II
Technical Plan:

1) Continue operating all existing and future municipal treatment plants at the existing permitted level.

2) Consider elimination of the phosphorous control based on the results of the recommended eutrophication study.

3) A monitoring program should be instituted to develop steady-state and nonsteady-state water quality simulation models for the segment.

4) Maximum limits on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Based on the preferred plan, Table VIII-8 presents a list of the municipal treatment systems projected for Dickinson Bayou. Geographical planning areas are presented in Exhibit IV-2.

TABLE VIII-8
PROJECTED MUNICIPAL TREATMENT SYSTEMS
DICKINSON BAYOU

Geographical Planning Areas	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
DB-1	4	4	5.18	2

The preferred plan for the Dickinson Bayou drainage basin is designed to develop the tools and information required to accurately evaluate the existing and future water quality needs of the area. Dickinson Bayou is a classified segment with major recreational potential and, therefore, future planning based on a sound foundation is required. The selected plan will maintain the existing water quality in the area and allow for future controls as necessary.

Houston Ship Channel

The preferred alternative technical subplan for the Houston Ship Channel and associated bays is to maintain the permitted level of control presently existing in the basin while developing information to update and verify the data base. The plan was selected due to the relatively good water quality predicted by the steady-state model and the questionable results predicted by the nonsteady-state model.

The steady-state model indicates that water quality in the Houston Ship Channel is most critical at the turning basin, where a dissolved oxygen concentration of 4.0 mg/l is predicted. Results further indicate that the turning basin water quality is dominated by the tributary bayous (Buffalo, Brays, and Sims) and relatively unaffected by direct point source dischargers to the Ship Channel. The overall impact of this fact is that according to the steady-state model, increased wasteload capacity is available in the lower portion of the Ship Channel and existing allocations could be increased without greatly affecting the water quality.

The nonsteady-state model predicts long periods of extremely low dissolved oxygen (less than 1.0 mg/l) following major storm events.

This would indicate that fish kills should be evident following a major storm. Since this has not been presently verified, the wet weather model results are considered questionable.

Specific elements of the preferred plan are as follows:

Segments: 1005, 1006, 1007, 2426, 2427, 2428, 2429, 2430
Water Quality Level Achieved: III
Technical Plan:

1) Reduce the desired D.O. concentration defined by Water Quality Level III from 5.0 mg/1 to 4.0 mg/1 in segments 1006 and 1007.

2) Continue operating all existing and future municipal treatment systems contributing to the total load in the Houston Ship Channel at their presently permitted values.

3) Continue nonregional municipal wastewater treatment.

4) Refine the steady-state Ship Channel model to incorporate major dischargers to tributaries and thus improve the continuity and predictive accuracy of the model.

5) Continue to calibrate, verify, and update the steady-state model to more accurately determine the additional wasteload allocation available in the Ship Channel as presently predicted by the model.

6) The nonsteady-state water quality model predicts major nonpoint source related water quality problems. A monitoring program should be instituted to calibrate, update and verify the nonsteady-state model.

7) If wet weather monitoring concludes that the non-steady state model accurately predicts the water quality in the Houston Ship Channel, the Ship Channel should be reclassified as an industrial channel not capable of meeting fishable/swimmable water quality.

Based on the preferred plan, Table VIII-9 presents a list of the municipal treatment systems projected for the Houston Ship Channel area. Geographical planning areas are presented in Exhibit V-2.

TABLE VIII-9
PROJECTED MUNICIPAL TREATMENT SYSTEMS
HOUSTON SHIP CHANNEL

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
HSC-1	2	2	1.56	2
HSC-2	1	1	0.88	2
HSC-3	3	4	10.60	
HSC-4	2	2	6.40	2
HSC-5	1	1	0.58	2
TOTAL	9	10	20.02	

The preferred plan for the Houston Ship Channel requires updating, calibration, and verification of the simulation models. Implementation of the preferred plan for the Houston Ship Channel is dependent upon further investigation of wet weather water quality. The wet weather water quality indicates such a severe wet weather water quality problem (dissolved oxygen values of less than 1.0 mg/l for extended time periods) that maintenance of the Ship Channel as a fishable/swimmable stream is not possible. Since doubt is cast on the validity of the model's dissolved oxygen prediction because those results do not correlate with present day observations, wet weather water quality monitoring should be performed to verify or refute the projections of the wet weather model. If the model results are verified, expenditure of funds on point source controls to maintain fishable/swimmable quality during dry weather would not be cost-effective.

If future monitoring indicates that stormwater related conditions do not impact on the ability to maintain fishable/swimmable water quality, the Houston Ship Channel water quality could be upgraded through the use of supplemental in-stream aeration to increase the dissolved oxygen concentration to 5.0 mg/l. Additionally, wasteload allocations could be increased downstream and their effects on dissolved oxygen concentration at the critical point could be offset by increasing the amount of supplemental aeration.

It is obvious that further information must be developed prior to initiating any controls beyond those already existing for the basin. The preferred plan raised some interesting possibilities that may greatly affect the future economics of industry operating along the Houston Ship Channel and, therefore, a thorough monitoring program must be initiated as part of the preferred plan.

San Jacinto River

The preferred alternative technical subplan for the San Jacinto River is to maintain the existing permitted treatment level of point source dischargers. No controls are required for stormwater related nonpoint source wasteloads. The plan was selected because it is projected to achieve the goal of fishable/swimmable water quality during the critical low flow condition. The water quality projected during major storm events also achieves the desired criteria defined for dry weather conditions except near the interface with the Houston Ship Channel. Therefore, no additional controls are anticipated to maintain the water quality. However, control of nonpoint source suspended solids should be considered for reasons other than resultant water quality as detailed in Chapter VII.

The nonregional concept of municipal sewage treatment is recommended due to the obstacles of fully evaluating and implementing a regional treatment facility until the management system is implemented. However, where detailed planning studies dictate that regional systems be instituted, these studies should take precedence to the preferred plan.

Specific portions of the preferred plan are as follows:

Segment: 1001
Water Quality Level Achieved: III
Technical Plan:

1) Continue operation of existing and future municipal point source dischargers at their existing permitted levels.

2) Continue nonregional municipal sewage treatment except as dictated by detailed planning studies.

3) Municipal dischargers existing: 9
   Municipal dischargers projected: 10

4) Nonpoint source wasteload controls are not required. However, further monitoring should be performed to verify stormwater model conclusions.

5) Specific controls for nonpoint source suspended solids may be implemented for reasons not directly related to water quality, such as erosion control, on a case by case analysis.

6) Maximum limits on chlorine residuals from wastewater treatment systems should be considered by the TDWR.

Based on the preferred plan, Table VIII-10 presents a list of the projected municipal treatment systems for the San Jacinto River. Geographical planning areas are presented in Exhibit VI-2.

TABLE VIII-10
PROJECTED MUNICIPAL TREATMENT SYSTEMS
SAN JACINTO RIVER

Geographical Planning Area	Number Existing	Number Projected	Flow(MGD) Projected	Level of Treatment
SJ-1	6	7	1.79	2
SJ-2	3	3	0.60	2
TOTAL	9	10	2.39	

The preferred plan for segment 1001 of the San Jacinto River Basin is designed to maintain the desired level of water quality in the area. The simulation model indicates that the Houston Ship Channel exhibits the greatest single influence on the water quality of the lower San Jacinto River. Some of the Houston Ship Channel results are questionable, as previously discussed. Therefore, further monitoring of San Jacinto River is required to confirm the model's predictions that the fishable/swimmable water quality goal will be achieved in this segment without requiring any additional controls.

Buffalo Bayou

Buffalo Bayou has been singled out from the remaining unclassified segments in the 208 Planning Area because of its special significance and historic importance to the Houston Area. The preferred plan includes classifying Buffalo Bayou for noncontact recreation and preservation of aesthetics, while developing water quality criteria consistent with the proposed classification.

Specific portions of the preferred plan are as follows:

Segment: Unclassified
Water Quality Level Achieved: II
Technical Plan:

1) A specific model should be developed or the Houston Ship Channel model should be expanded to include Buffalo Bayou.

2) Wasteload allocations consistent with noncontact recreation can then be determined.

3) A wet weather water quality monitoring program should be initiated to verify the assumed storm water related conditions.

The preferred plan for Buffalo Bayou is based on preserving the natural beauty of the bayou and allowing for noncontact recreation. Based on the recommended plan, there are projected to be 18 municipal treatment plants (17 presently exist) discharging a total of 164 MGD to Buffalo Bayou. All plants will operate at effluent set 2 except for the Northside/69th Street Complex which will operate at effluent set 2N.

Remaining Unclassified Bayous

The preferred alternative technical subplan for the remaining unclassified bayous (Brays, Carpenters, Greens/Halls, Hunting, Sims, Vince, and White Oak) is to maintain the permitted level of control presently existing in those basins. This plan was selected because these bayous are not considered to hold a recreational potential. These bayous serve two major purposes. They are conveyance systems for effluent from treatment systems throughout the 208 area, and they are drainage channels to direct stormwater out of potentially flood prone areas.

The costs involved in converting these bayous into fishable/swimmable streams is not warranted and, therefore, no additional controls are recommended from a water quality aspect.

Table VIII-11 presents the number of projected municipal treatment systems for each of the unclassified bayous associated with the preferred plan.

TABLE VIII-11
PROJECTED MUNICIPAL TREATMENT SYSTEMS
UNCLASSIFIED BAYOUS

Bayou	Number Existing	Number Projected	Flow (MGD) Projected	Level of Treatment
Brays	19	24	60.7	2
Carpenters	4	3	0.7	2
Greens/Halls	44	28	22.8	2
Hunting	4	5	5.8	2
Sims	11	14	130.0	2*
Vince	2	3	7.9	2
White Oak	11	11	20.9	2

* Except for Sims Bayou Treatment Plant which is permitted at 2N.

APPENDIX A

WATER QUALITY SIMULATION MODELS

APPENDIX A - WATER QUALITY SIMULATION MODELS

Introduction

Several water quality simulation models were utilized during the segment analysis portion of the 208 Areawide Water Quality Model Simulation. Table A-1 lists the streams for which dry weather water quality simulations were performed, the model utilized, the source of the model, and the type of model with respect to validity (see following section). Table A-2 presents the same information for wet weather simulations. Information relative to the models is presented subsequently.

Validity of Models Utilized

During the development of the Segment Analysis numerous water quality simulation models were utilized. These models had varying degrees of precision and can be grouped as follows:

- simplified,
- nonspecific
- uncalibrated/unverified
- calibrated/unverified
- calibrated/verified

Each type of model is discussed below.

Simplified models are the least accurate tools utilized. While typical equations for dissolved oxygen utilization and re-aeration are utilized, simplifying assumptions are made such as a completely mixed receiving body of water.

Nonspecific models utilize the classical Streeter-Phelps D.O. sag simulation, however, the critical constants such as degradation rates, re-aeration rates and stream hydraulics are not determined for that stream. Rather, these constants are estimated through a variety of techniques; literature values, values reported for other streams in the area, and analysis of topographic maps. The Weston SAC-III model and the EPA simplified models are nonspecific models.

Uncalibrated/unverified models again utilize typical formulations for D.O. sag predictions. Some of the constants may be developed uniquely for that stream while others may be obtained from other models developed for that stream. However, intensive sampling is not done to determine each constant and develop constants which are consistent with

TABLE A-1
WATER QUALITY MODEL INFORMATION
DRY WEATHER

Water Body	Model Name	Source of Model	Type of Model
Clear Creek (nontidal)	QUAL-II	TDWR	Calibrated/unverified
Cypress Creek	QUAL-II	TDWR	Calibrated/unverified
Spring Creek	QUAL-II	TDWR	Calibrated/unverified
Clear Creek (tidal)	EPA Simplified	EPA	Nonspecific
Clear Lake	EPA Simplified	EPA	Nonspecific
Dickinson Bayou (nontidal)	-	-	Allowance load taken from TDWR wasteload allocation
Lake Houston	Lake model	Roy F. Weston, Inc.	Simplified
Armand Bayou	EPA Simplified	EPA	Nonspecific
Dickinson Bayou (tidal)	EPA Simplified	EPA	Nonspecific
Houston Ship Channel	O'Connor-Hydroscience	TDWR	Calibrated/verified
San Jacinto River	AUTO-SS	TDWR	Calibrated/unverified
Brays Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific
Buffalo Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific
Carpenters Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific
Greens/Hall Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific
Hunting Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific
Sims Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific
White Oak Bayou	SAC-III	Roy F. Weston, Inc.	Nonspecific

TABLE A-2
WATER QUALITY MODEL INFORMATION
WET WEATHER

Water Body	Model Name	Source of Model	Type of Model
Clear Creek	WRECEV	TDWR	Uncalibrated/unverified
Cypress Creek	WRECEV	TDWR	Uncalibrated/unverified
Houston Ship Channel	WRECEV	TDWR	Uncalibrated/unverified
San Jacinto River	WRECEV	TDWR	Uncalibrated/unverified
Spring Creek	WRECEV	TDWR	Uncalibrated/unverified

the dissolved oxygen concentrations observed during sampling.

Calibrated/unverified models utilize typical formulations for D.O. sag predictions. Most, if not all, of the constants are developed uniquely for that stream. Inputs to the stream are measured, stream quality is analyzed, constants are calculated, comparisons of stream D.O. observed during sampling to that predicted by calculated constants are made, and constants are adjusted to close any differences between the calculated and observed D.O. values.

A calibrated/verified model utilizes the same techniques as the calibrated/unverified model to develop the basic constants. However, subsequent sampling is performed to measure inputs to the stream and stream D.O. concentration. The previously developed constants are utilized to predict stream D.O. and, if it compares closely to the measured D.O., the model is verified. It should be noted that models called calibrated/unverified are generally given such classification because no verification has been attempted, not because verification has been attempted unsuccessfully.

QUAL-II, AUTO-SS, WRECEV and EPA Simplified

Documentations for QUAL-II, AUTO-SS, WRECEV, and EPA simplified are available at H-GAC or TDWR.

SAC-III

The basic data and assumptions utilized for SAC-III are presented in Table A-3. Three items in that Table require additional comment.

- The re-aeration rate of 0.94/day is consistent with the EPA simplified model technique of setting $K_2/K_1 = 9.4$ (See Figure A-4 in that report.) A comparison can be made to the re-aeration rates utilized by TDWR for Spring and Cypress Creek.

  1. Equation $K_2\ (20^{\circ}C) = \dfrac{12.84\ V^{0.5}}{d^{1.5}}$

     $V = a\ Q^b$
     $d = c\ Q^d$

TABLE A-3
MAJOR INPUT CONSTANTS FOR SAC-III

Item	Value	Comment
D.O. of background flow	7.6 mg/1	Saturation
UBOD of background flow	1.0 mg/1	Includes nitrogenous and carbonaceous
D.O. of point source	4.0 mg/1	Consistant with TDWR allocation studies
Temperature	85°F	Stream standard
Re-aeration rate	0.94/day	Base 10
De-oxygenation rate (K_1)	0.10/day	Base 10
Background load (D.O.)	1.0 mg/1	A residual load consistent with the EPA simplified model
Velocity	0.1 fps	Estimated

2. Typical values for coefficients as obtained from QUAL-II models.

Creek	Reach	Typical Coefficients			
		a	b	c	d
Spring	1-4	.05	.5	1.3	.5
Spring	5,7	.06	.5	.8	.5
Spring	6,8	.1	.5	1.1	.5
Spring	12	.1	.5	.11	.5
Cypress	1-4	.113	.5	1.8	.5
Cypress	6,7	.113	.5	.6	.5

3. Find flow range where K_2 is greater than or equal to 0.94.

Creek	Reach	Flow Range for which Re-aeration Rate is greater than 0.94
Spring	1-4	0-4 cfs
Spring	5,7	0-25 cfs
Spring	6,8	0-16 cfs
Spring	12	0-900 cfs
Cypress	1-4	0-4 cfs
Cypress	6,7	0-100 cfs

4. Total sewage flow in SAC-III modeled tributaries.

Tributary	Total Sewage (cfs)
Buffalo	250
Brays	93
Carpenters	1
Greens/Hall	35
Hunting	9
Sims	200
Vince	12
White Oak	32

A comparison of the values in item 3 above to the values in item 4 above indicate that for the bayous which receive significant sewage flow (Buffalo, Brays, and Sims) the reaeration rate utilized in SAC-III may be high. Therefore, lower oxygen values than those predicted may be observed. However, this can only be verified by developing the hydraulic constants for the tributaries.

- De-oxygenation rate (0.10) is a typical value for municipal wastes and was utilized by TDWR on Spring and Cypress Creek models.

- Background load (1.0 mg/l) is a uniform sink which is subtracted from the predicted D.O. values to account for benthic demands and other nonpoint sources. This value is probably somewhat excessive when considering relatively high levels of treatment (effluent set 2 or better) and streams with relatively large flows (Buffalo, Brays and Sims). As flow increases the effect of a surface phenomena such as benthic demand is reduced.

Lake Model

Critical parameters input to the Lake Model are presented in Table A-4. The predicted dissolved oxygen level is greater than 6.0 mg/l.

TABLE A-4
INPUTS TO LAKE HOUSTON MODEL

Item	Value	Comment
Flow		
Spring Creek	41 cfs	From projected wasteloads
Other Tributaries	65 cfs	Low flow values and estimates
Point Sources to Lake	6.5 cfs	Projected wasteload
Temperature	85° F	Stream standard
Re-aeration	0.12/day	Base 10. Usual range of lakes .05-0.15
De-oxygenation	0.10/day	Base 10. Carbonaceous and Nitrogenous
Algae O_2 Production	0.73mgO_2/1/day	Data from EPA Areawide Procedures Assessment Manuals and Lake Houston Report
Algae O_2 Respiration	1.18mgO_2/1/day	R = 0.025 (Chla) Chla value = 47.2 from Lake Houston Report
Benthal Demand	0.65mgO_2/m^2/day	From EPA Areawide Assessment Procedures Manual
Outflow	0.0 cfs	Dry weather
Surface Area	12,240 acres	At spillway crest
Volume	146,700 acre feet	At spillway crest
Ultimate Oxygen Demand		
Carbonaceous	—	See Calculation 1
Nitrogenous	--	See Calculation 2
D.O. Levels		
Spring Creek	7.3 mg/1	From Spring Creek Model
Other Tributaries	7.6 mg/1	Saturation
Dischargers	4.0 mg/1	Assumed
Average	7.3 mg/1	See Calculation 3

TABLE A-4 (CONTINUED)
INPUTS TO LAKE HOUSTON MODEL

Calculations:

1. Ultimate Carbonaceous BOD
   Spring Creek 41 cfs at 6.2 mg/l = 1,380 lbs./day
   Point Sources 6.5 cfs at 7.5 mg/l = 260 lbs./day
   Tributaries 65 cfs at 1.5 mg/l = 530 lbs./day
   2,170 lbs./day

   At 112.5 cfs = 3.6 mg/l

2. Ultimate Nitrogenous BOD
   Spring Creek 41 cfs at 6.3 mg.1 = 1,400 lb/day
   Point Sources 6.5 cfs at 22 mg/l = 770 lb/day
   Tributaries 65 cfs at 1.5 mg/l = 530 lb/day
   2,700 lb/day

   At 112.5 cfs = 4.4 mg/l

3. Average D.O.

$$\frac{7.3(41) + 7.6(65) + 4.0(6.5)}{112.5} = 7.3 \text{ mg/l}$$

APPENDIX B

DISSOLVED OXYGEN PROFILES

FIGURE III - 4
SPRING CREEK
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT C

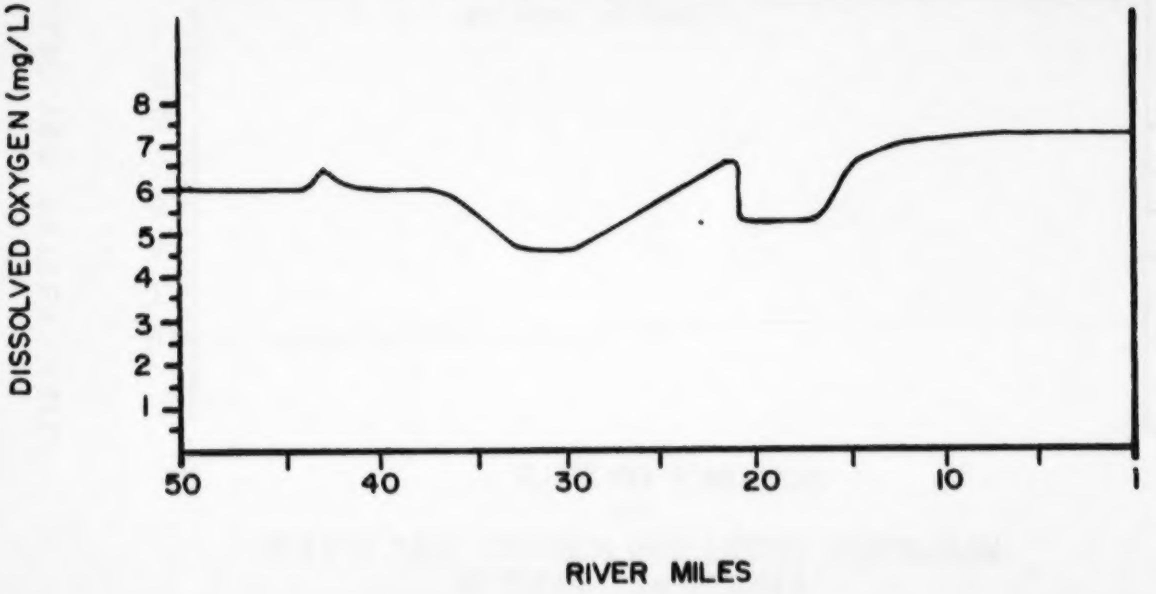


FIGURE III-5
SPRING CREEK
5 DAYS 24 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

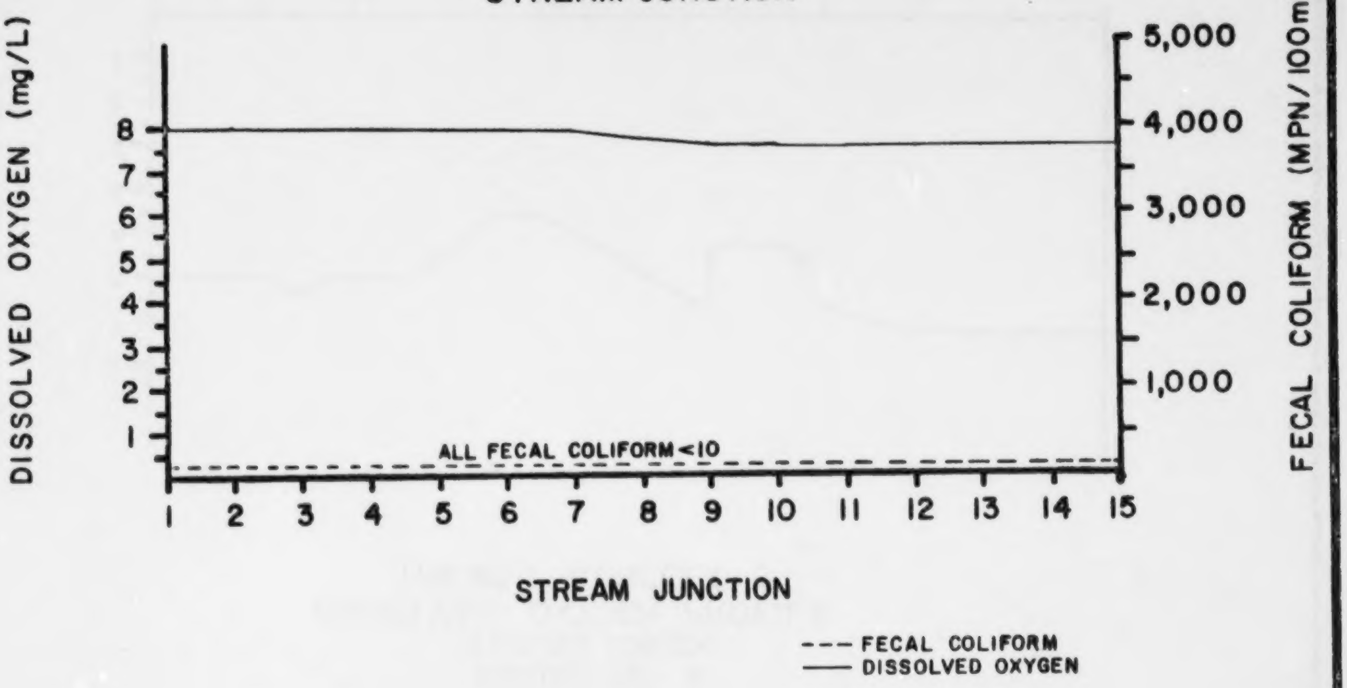


FIGURE III-6
SPRING CREEK
6 DAYS 2 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

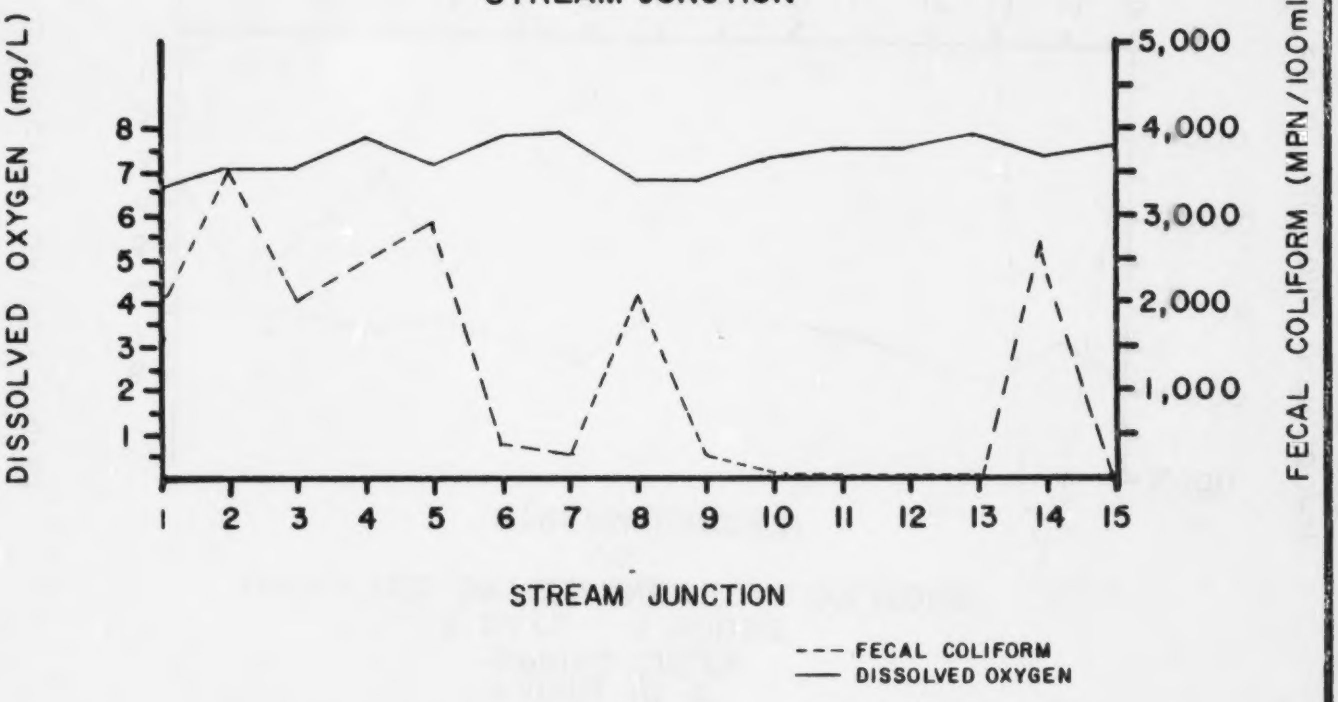


FIGURE III-7
SPRING CREEK
6 DAYS 4 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

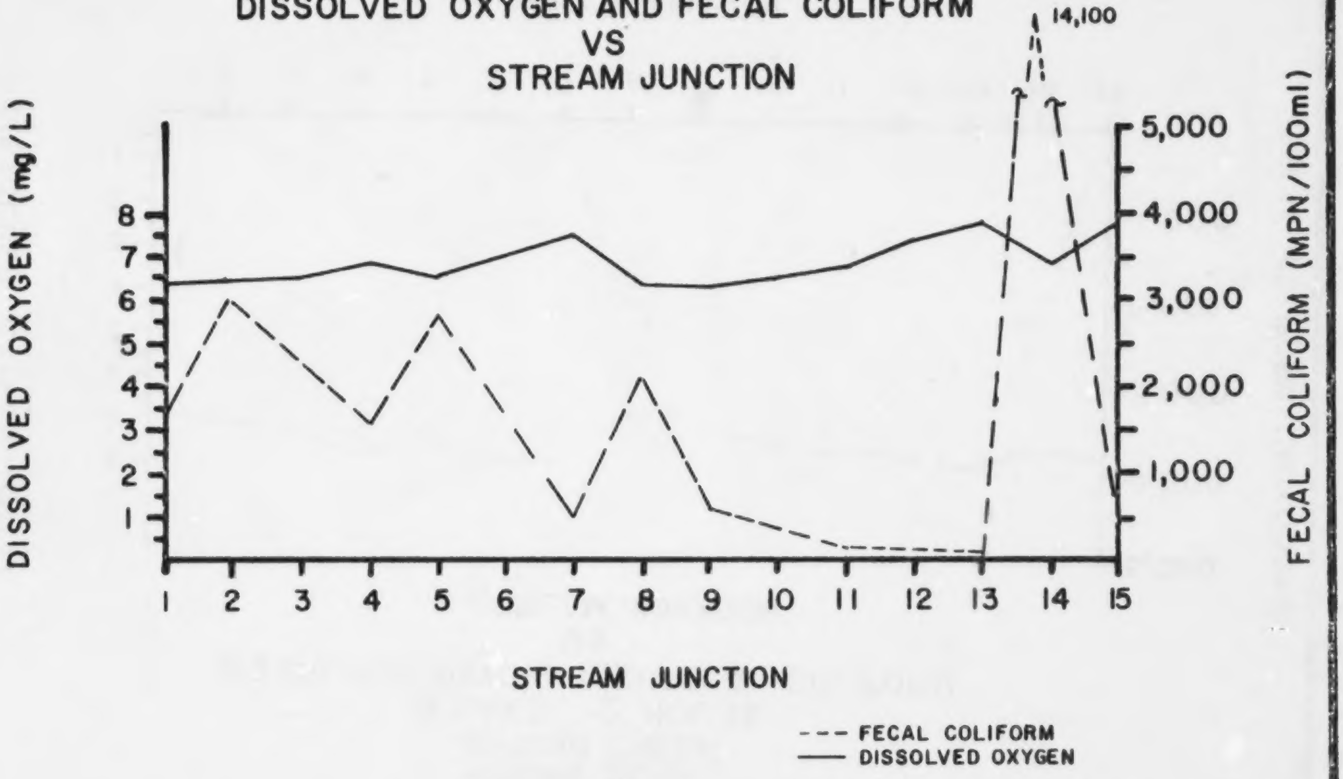


FIGURE III-8
SPRING CREEK
6 DAYS 6 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

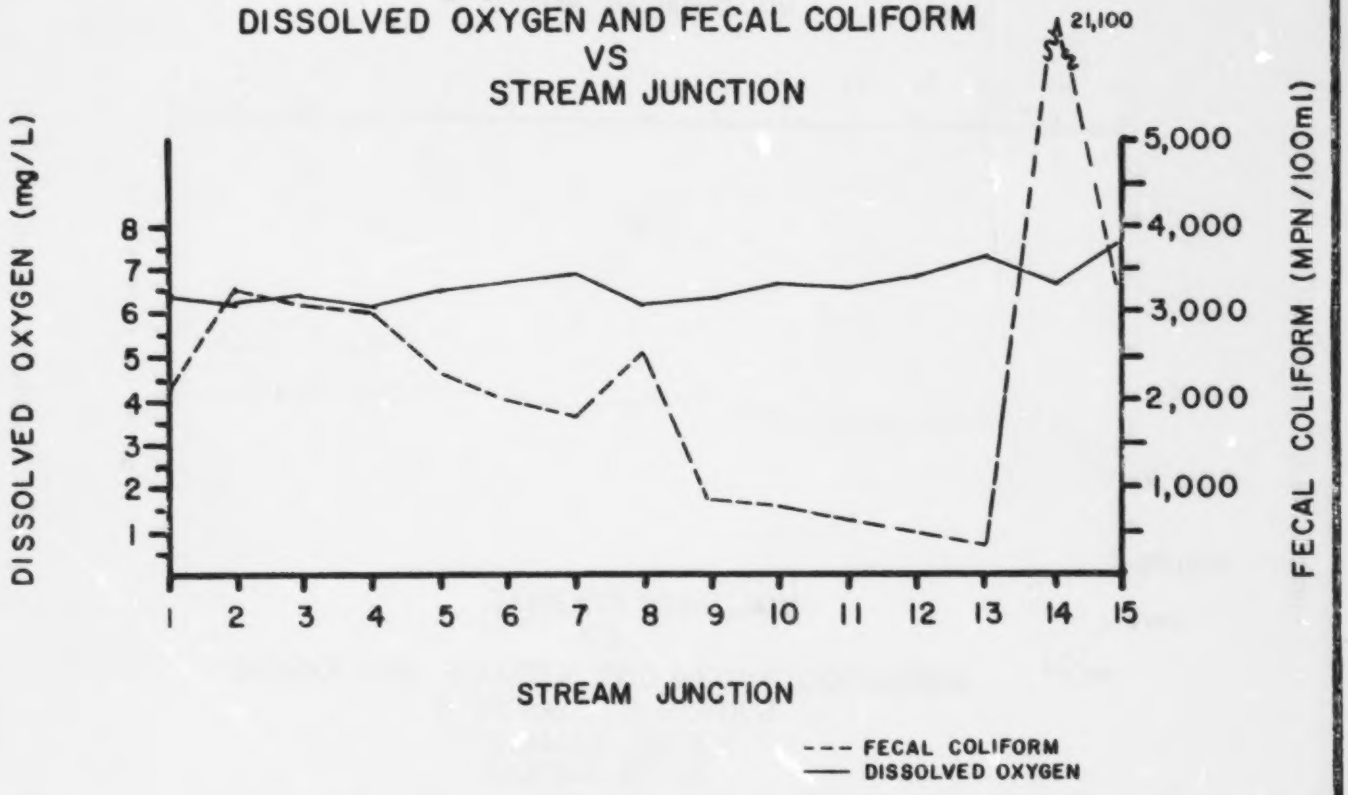


FIGURE III-9
SPRING CREEK
6 DAYS 8 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

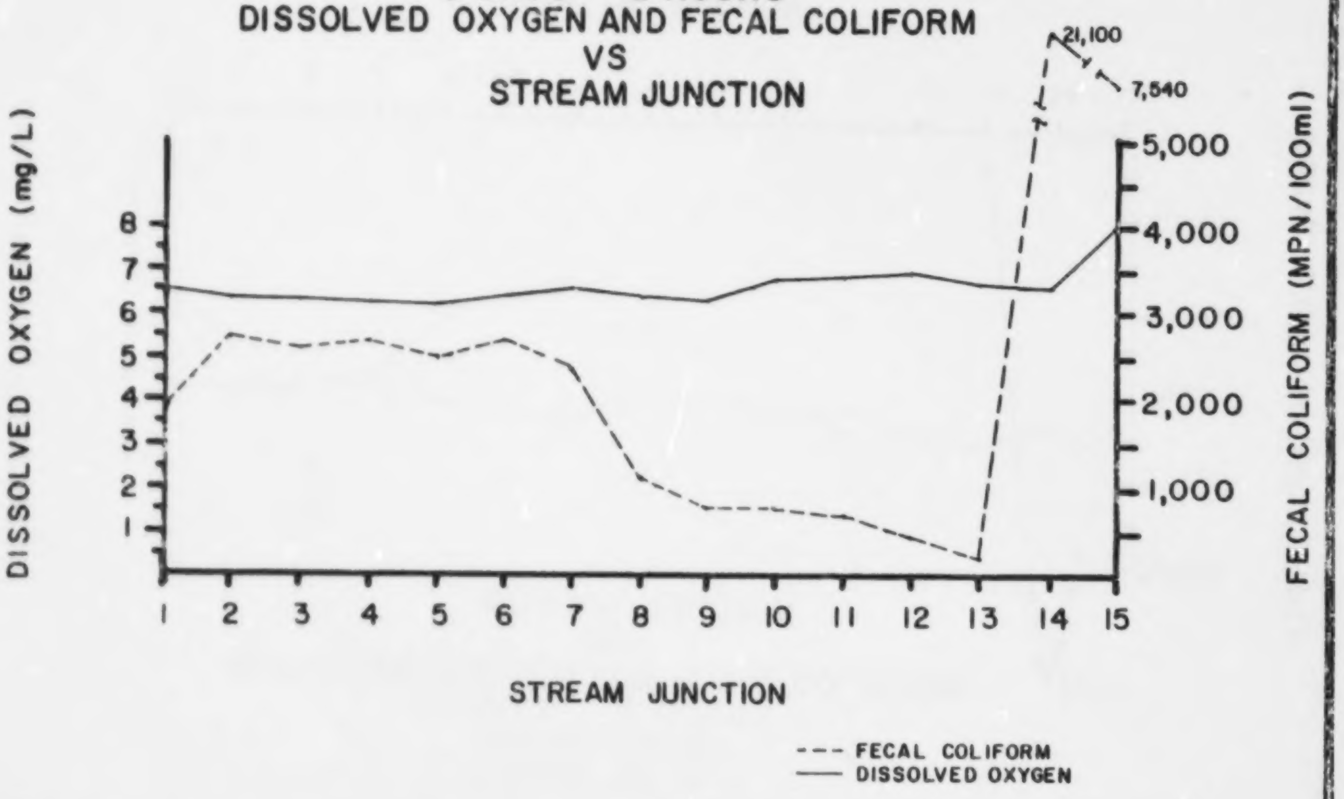
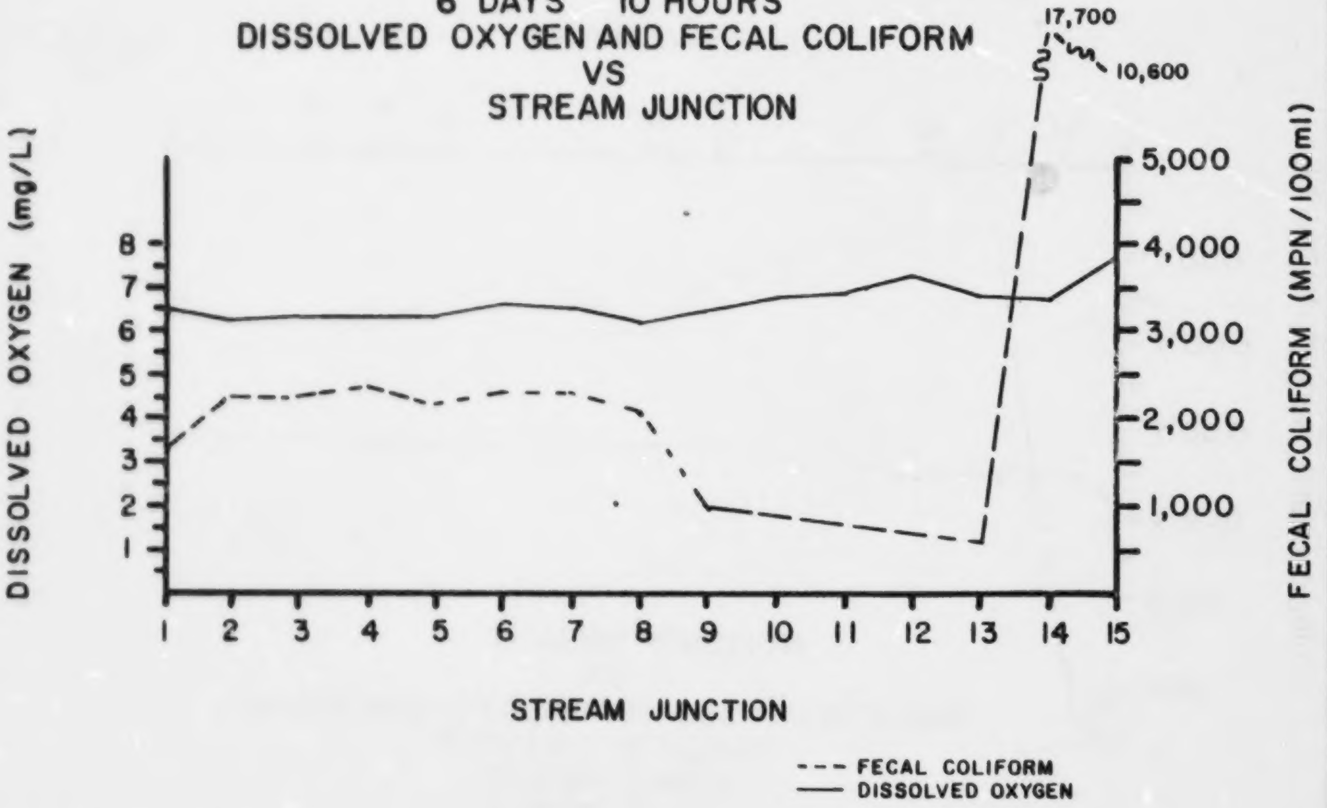


FIGURE III-10
SPRING CREEK
6 DAYS 10 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION



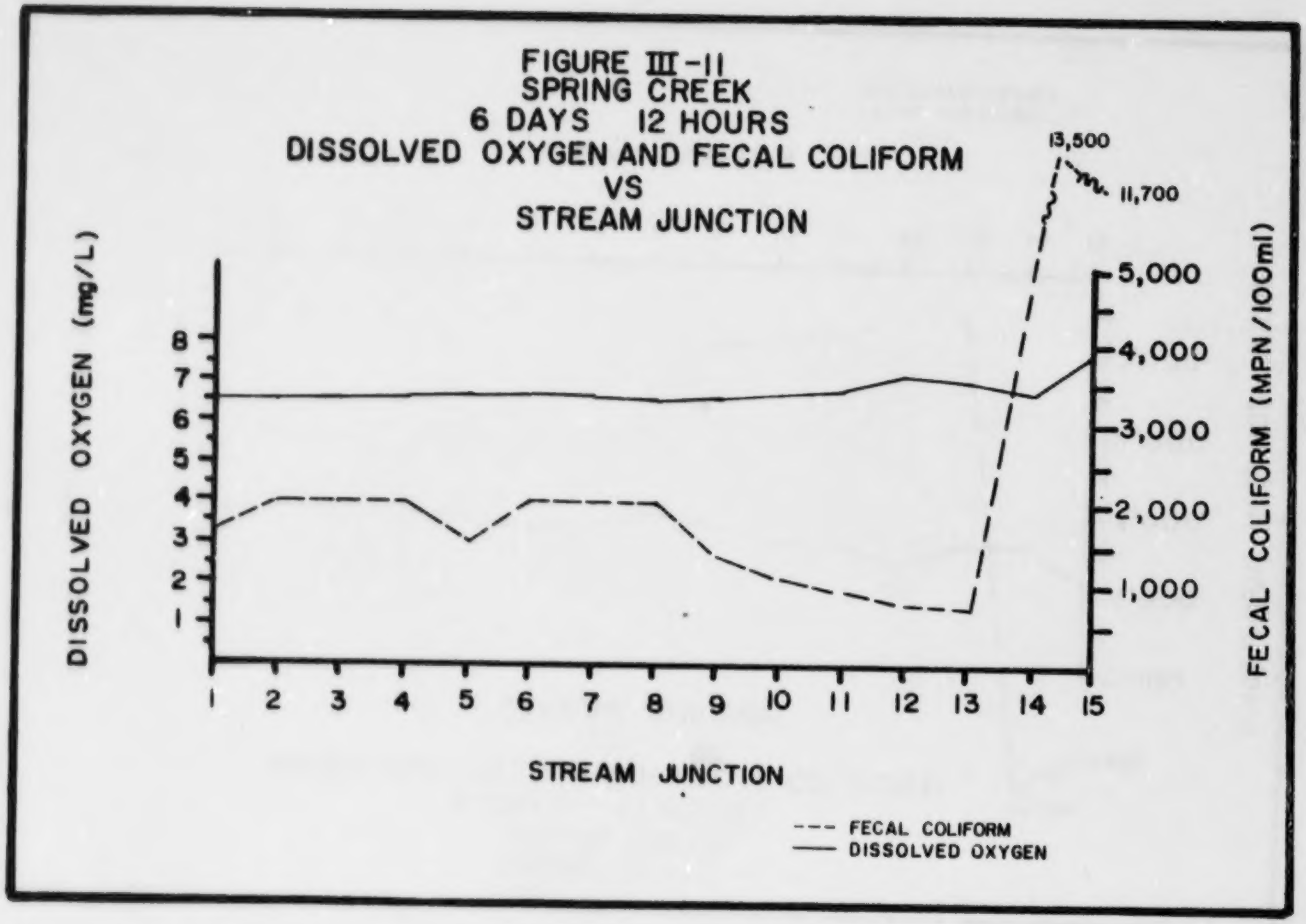


FIGURE III-11
SPRING CREEK
6 DAYS 12 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

FIGURE III-12
SPRING CREEK
6 DAYS 14 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

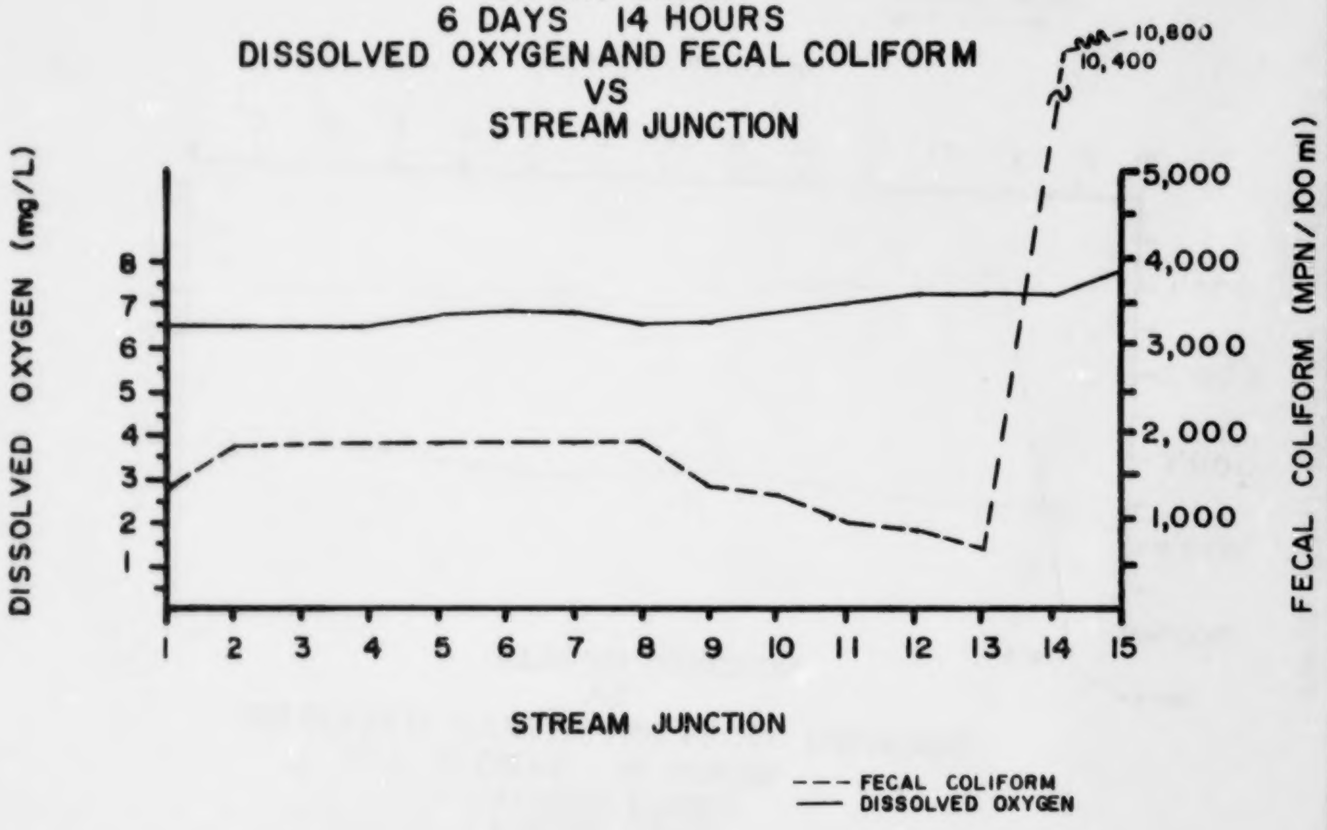


FIGURE III-13
SPRING CREEK
6 DAYS 16 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

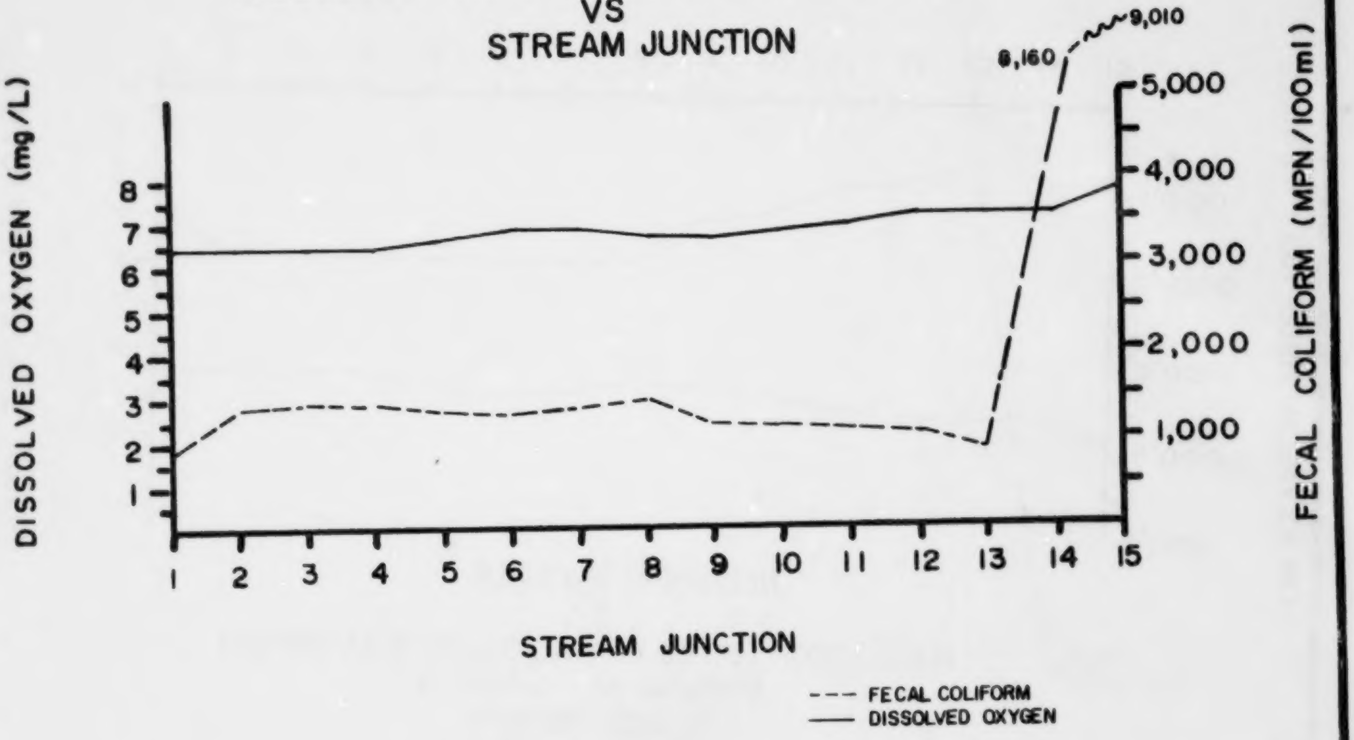


FIGURE III-14
SPRING CREEK
6 DAYS 18 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

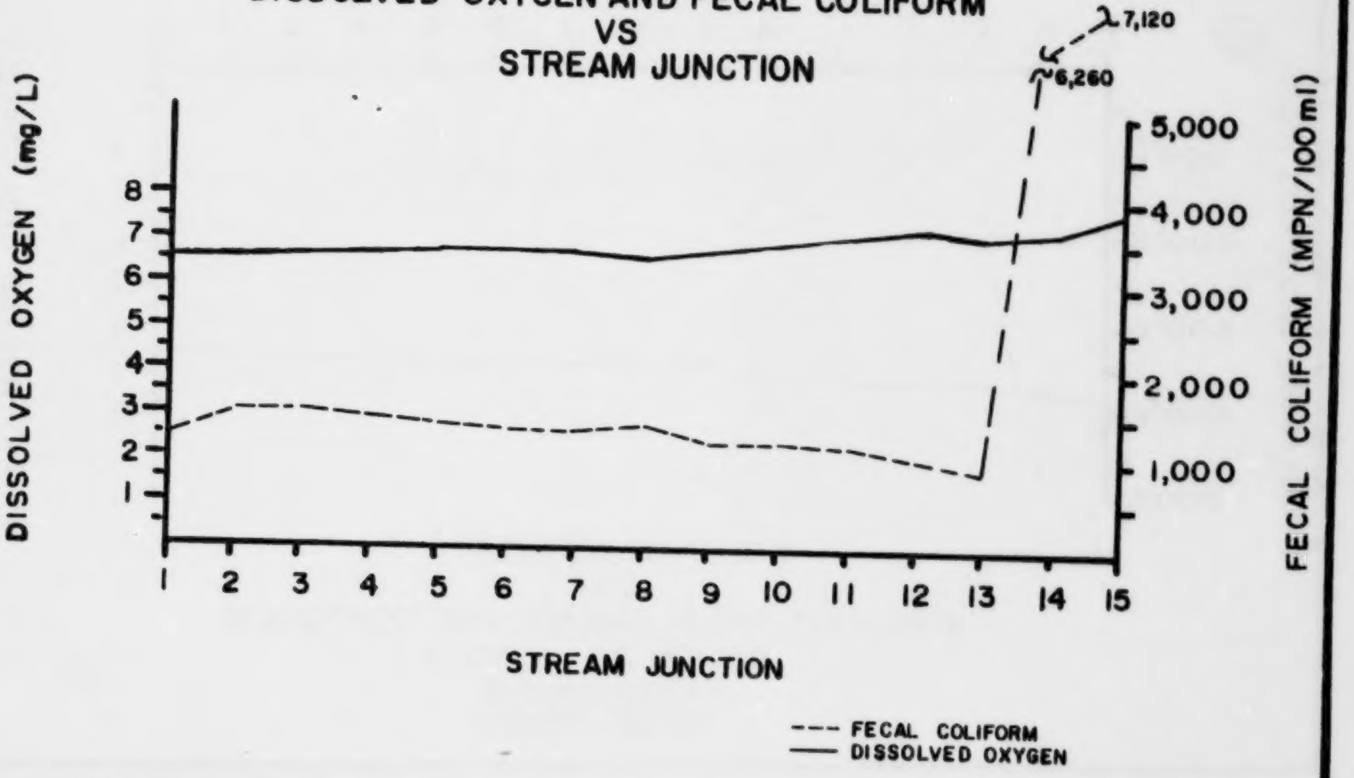


FIGURE III-15
SPRING CREEK
6 DAYS 20 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

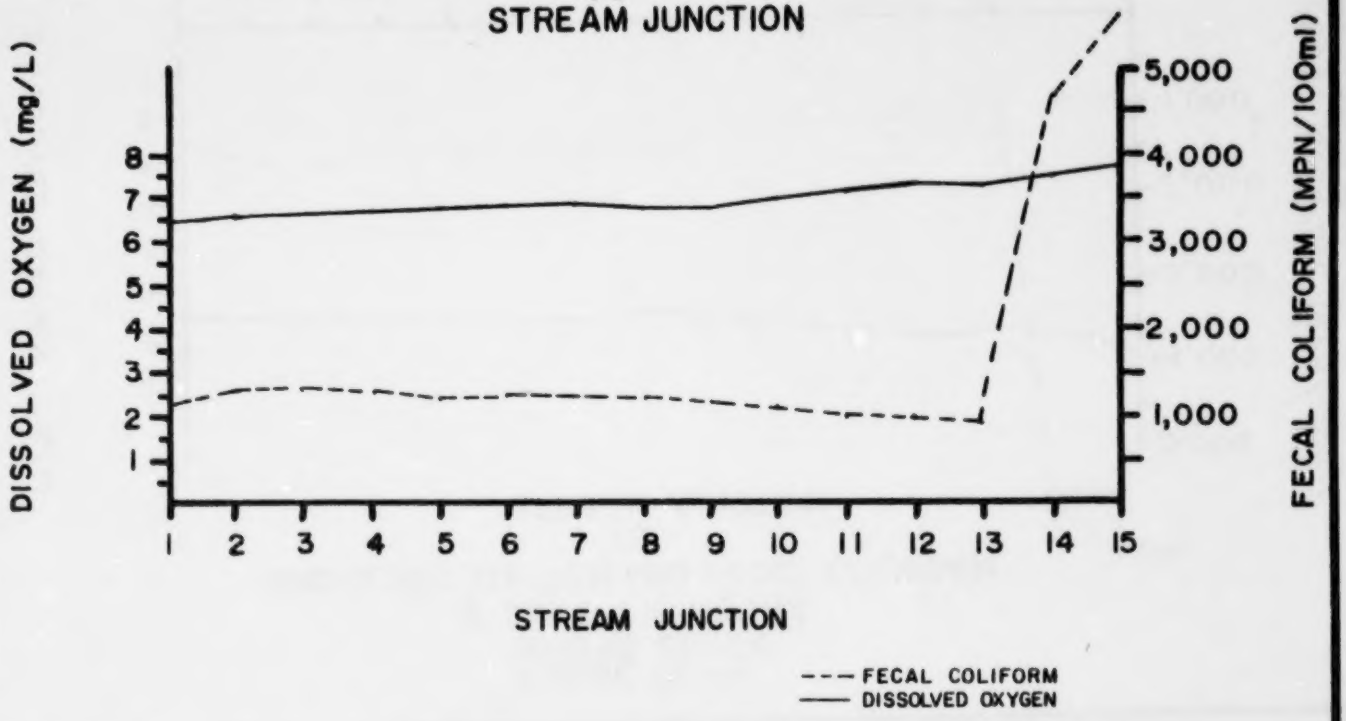


FIGURE III-16
SPRING CREEK
6 DAYS 22 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

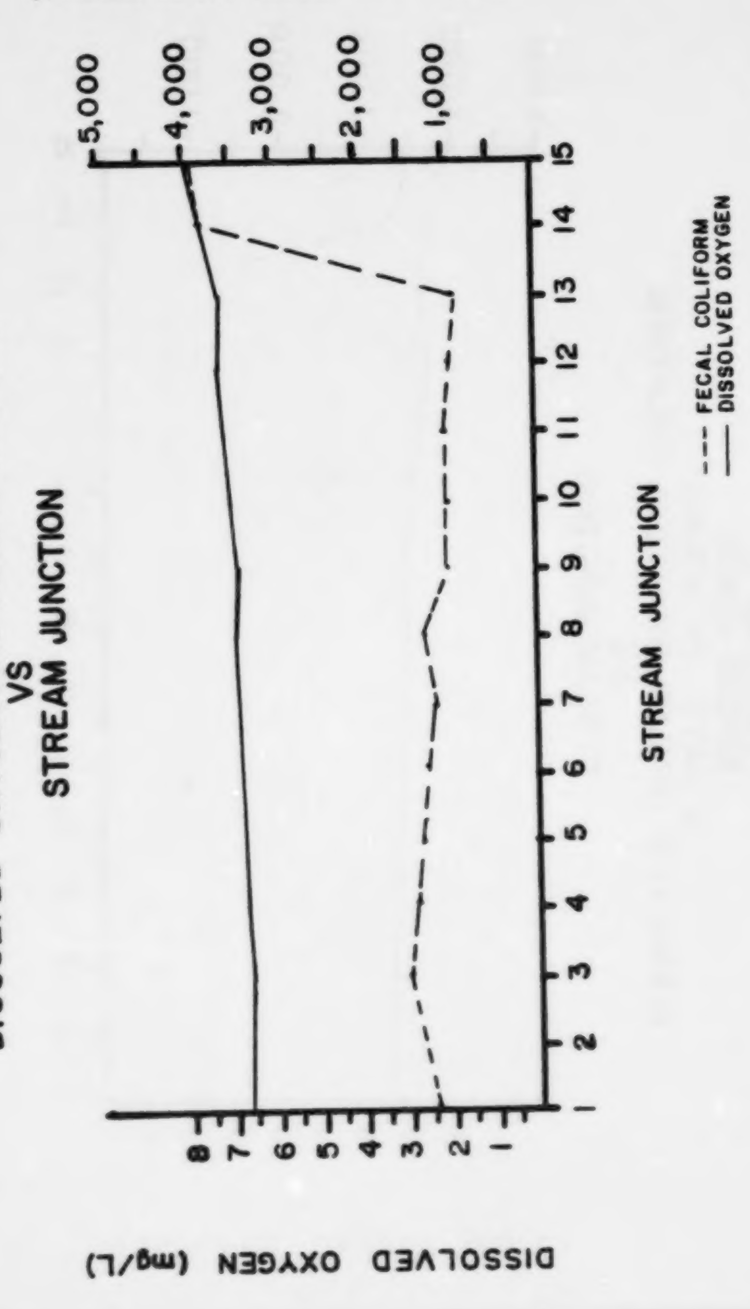


FIGURE III-17
SPRING CREEK
6 DAYS 24 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

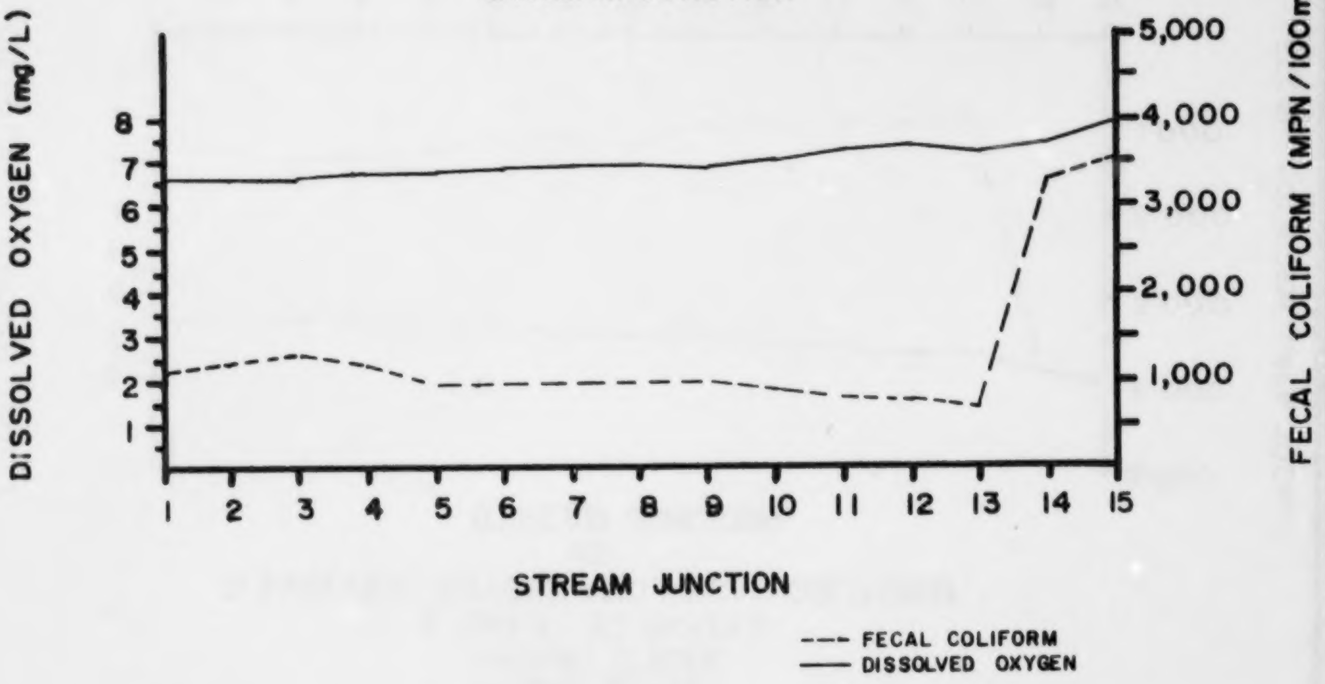


FIGURE III-18
SPRING CREEK
JUNCTION 14
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
TIME

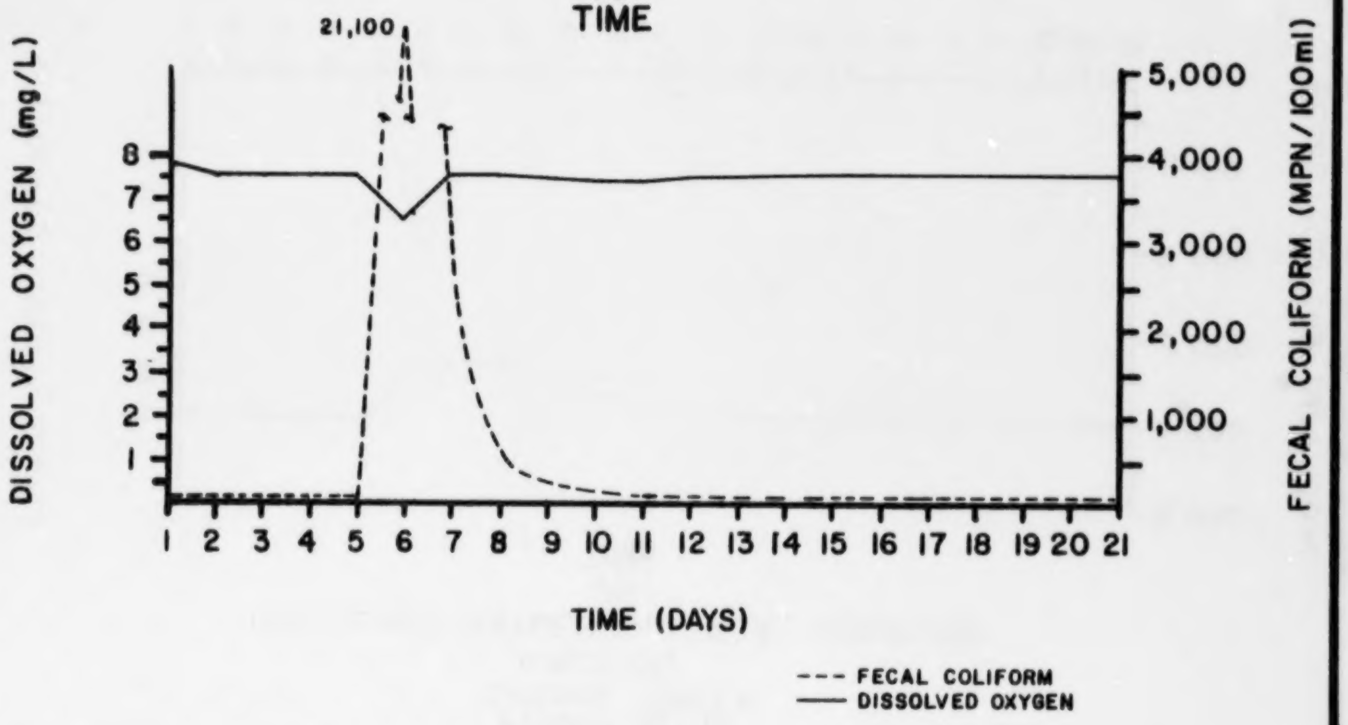


FIGURE III-19
SPRING · CREEK
JUNCTION I
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
TIME

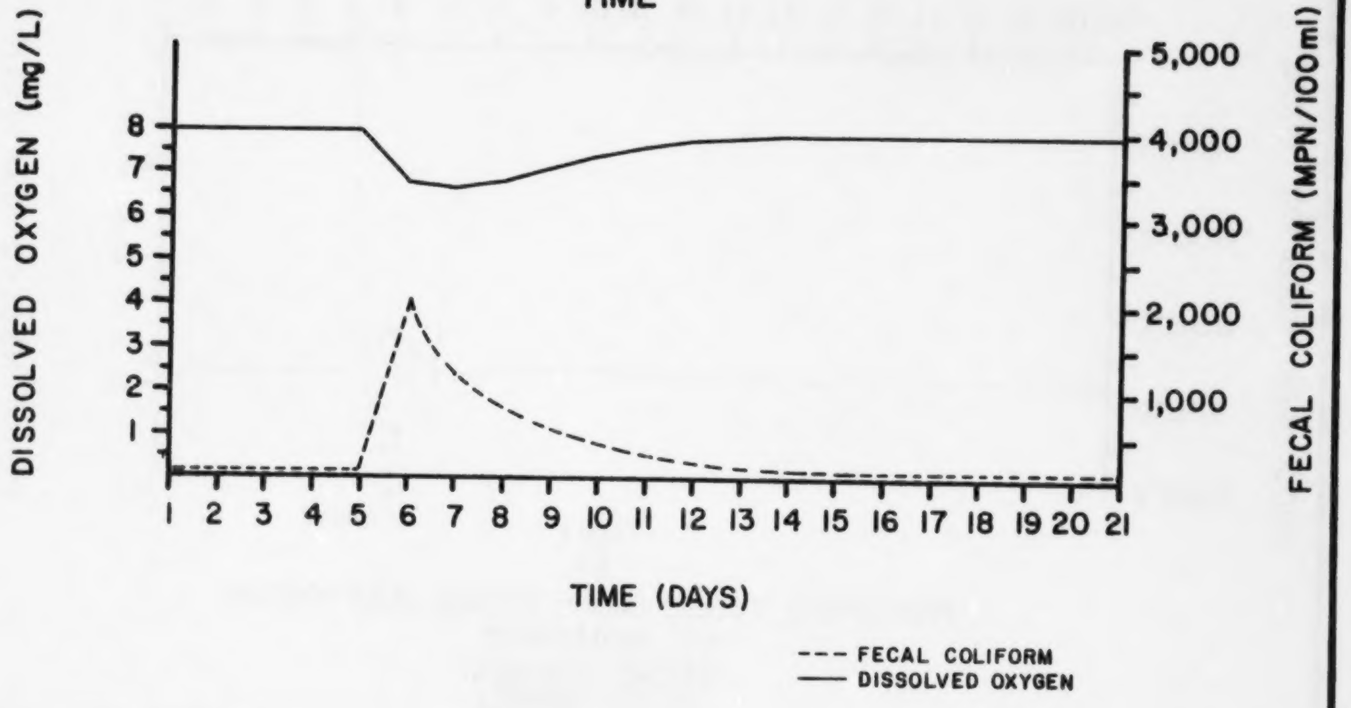


FIGURE III-20
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
BASELINE

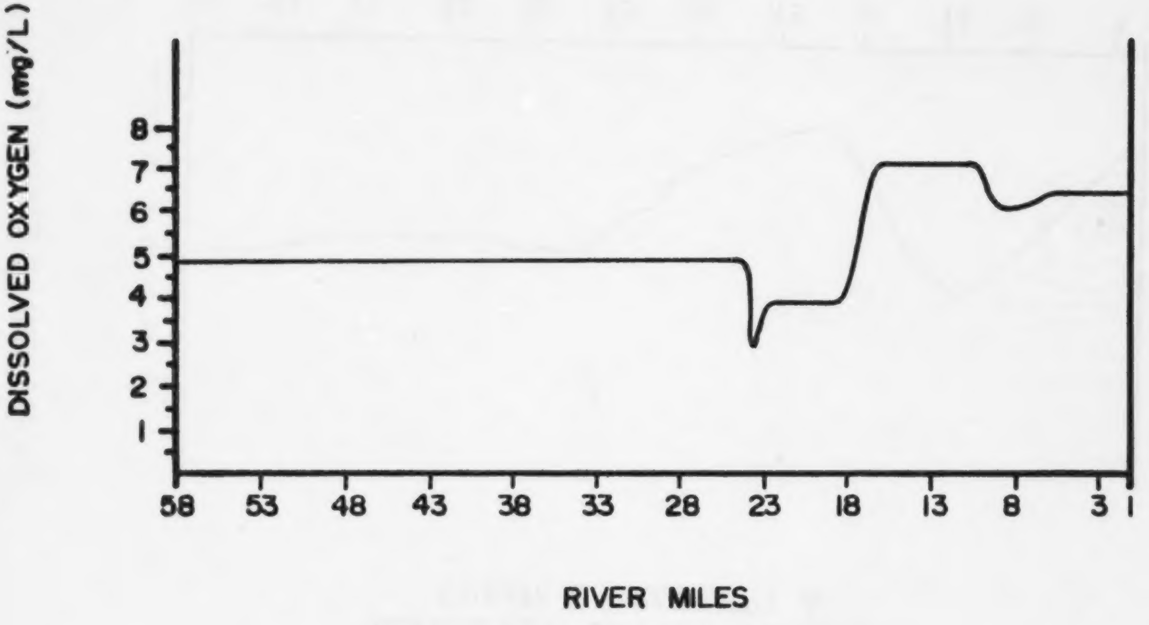


FIGURE III-21
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

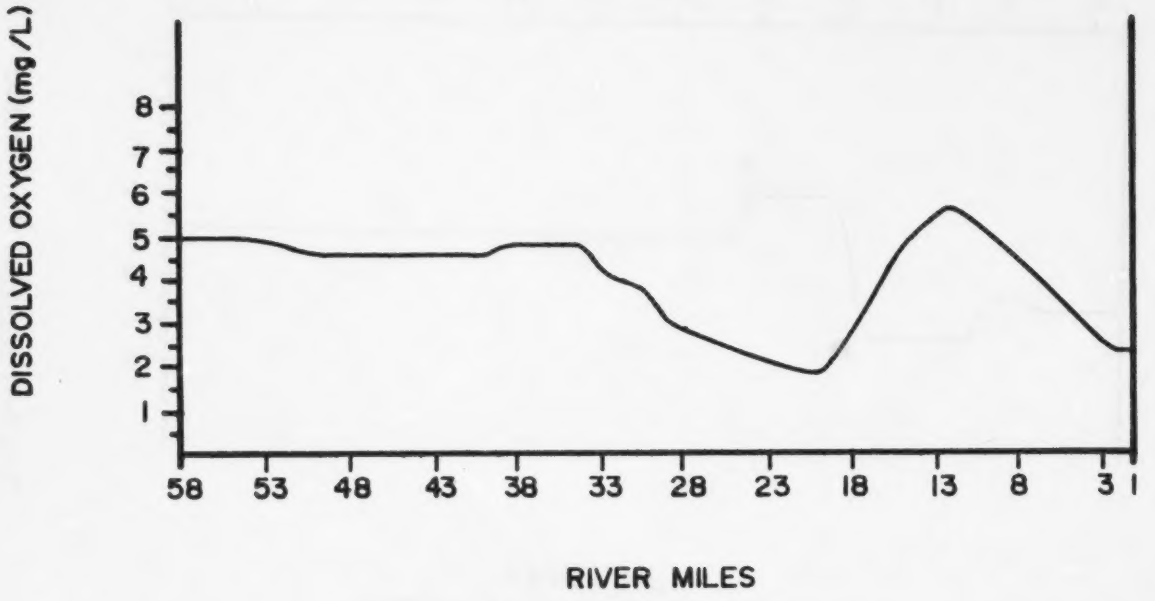


FIGURE III-22
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

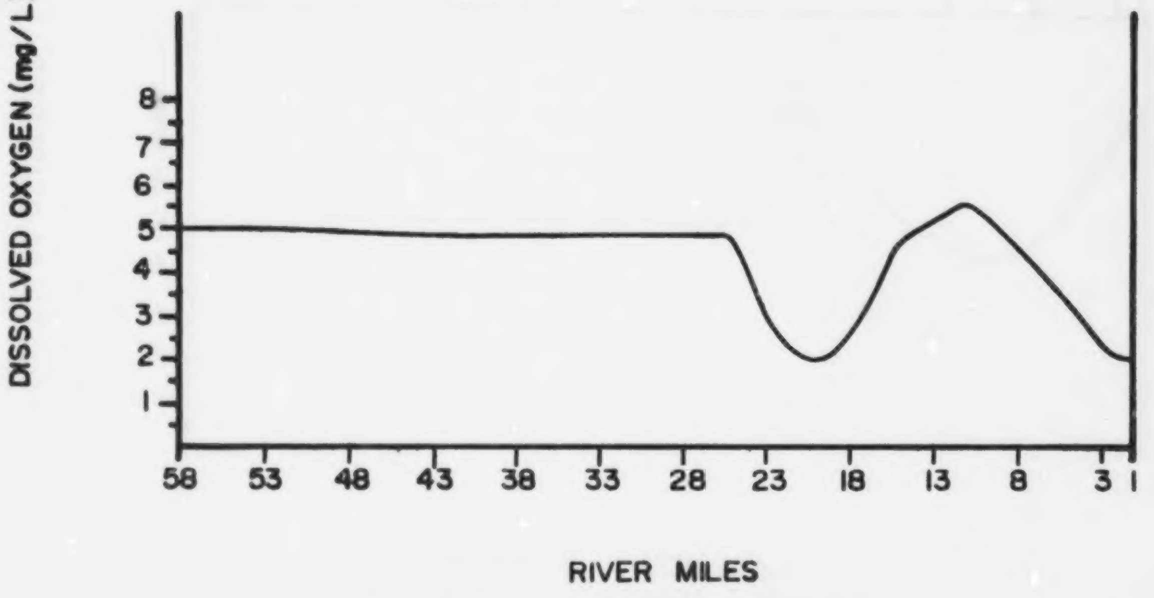


FIGURE III - 23
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

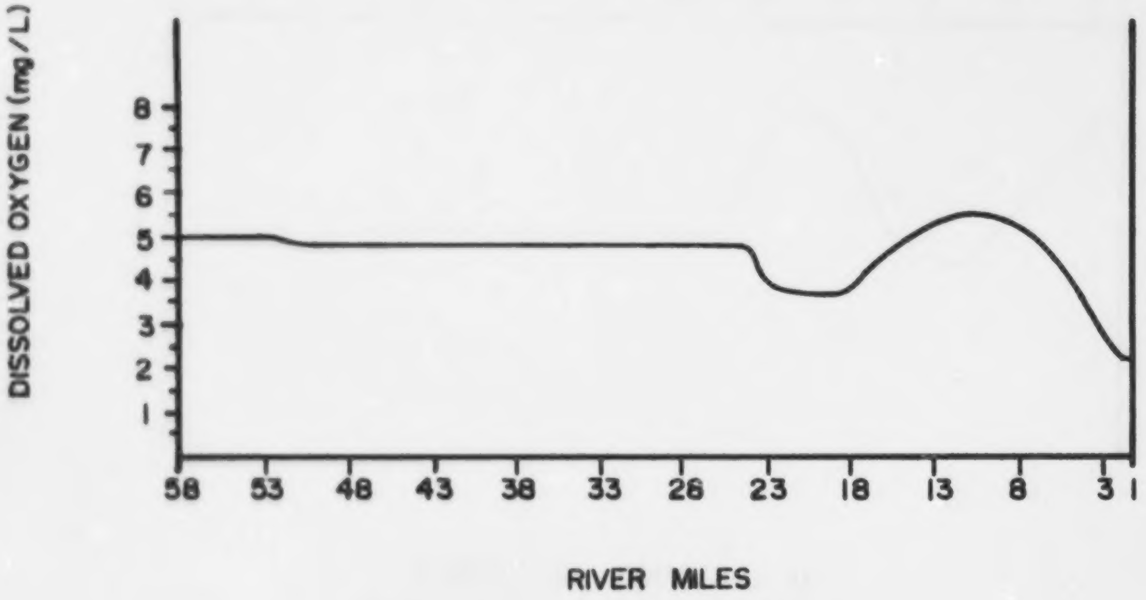


FIGURE III - 24
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT B
NO BENTHIC REDUCTION

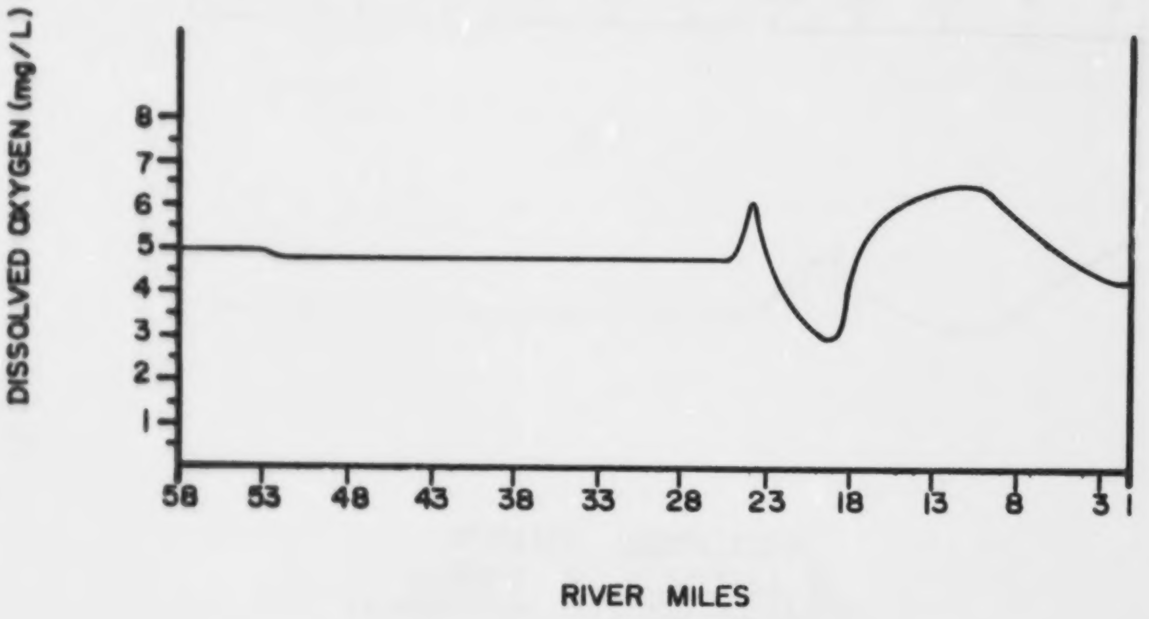


FIGURE III - 25
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT B
BENTHIC REDUCTION

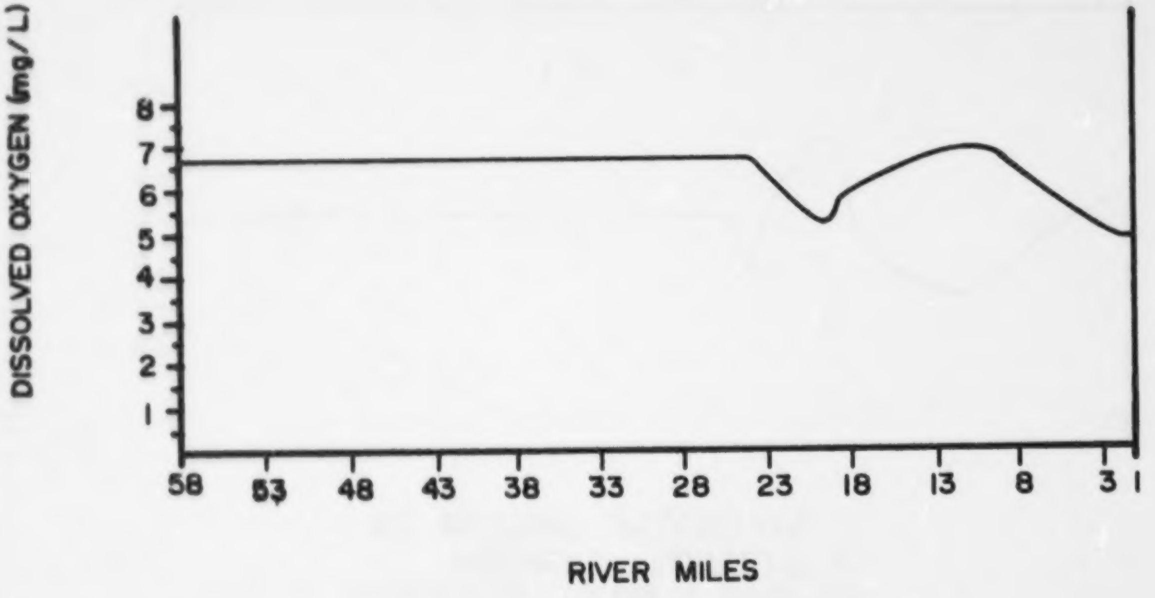


FIGURE III - 26
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 4 CONCEPT B
NO BENTHIC REDUCTION

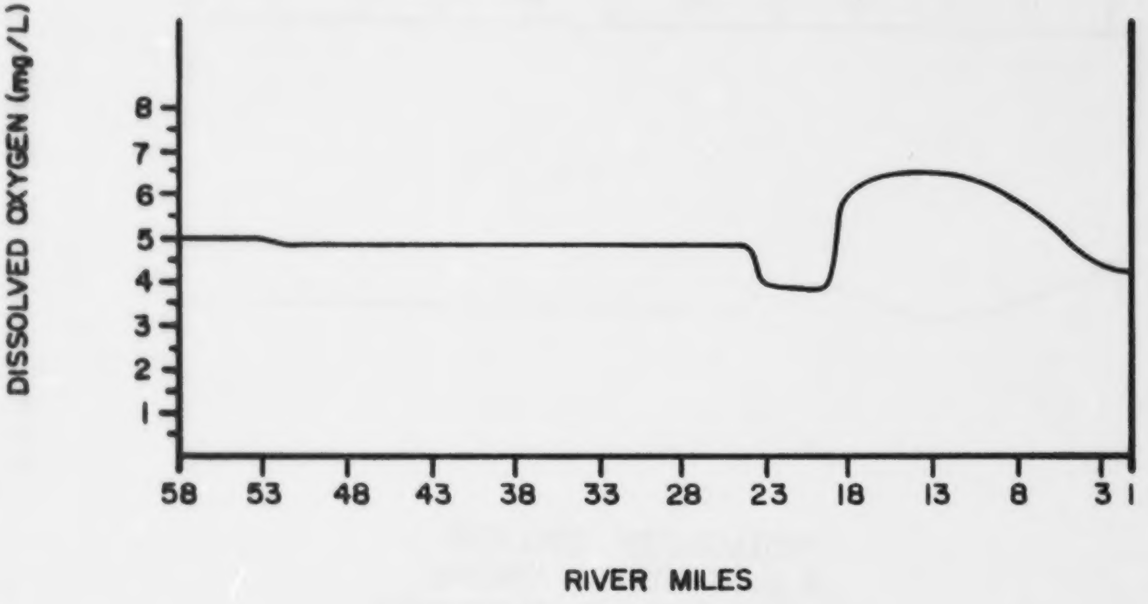


FIGURE III - 27
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 4 CONCEPT B
BENTHIC REDUCTION

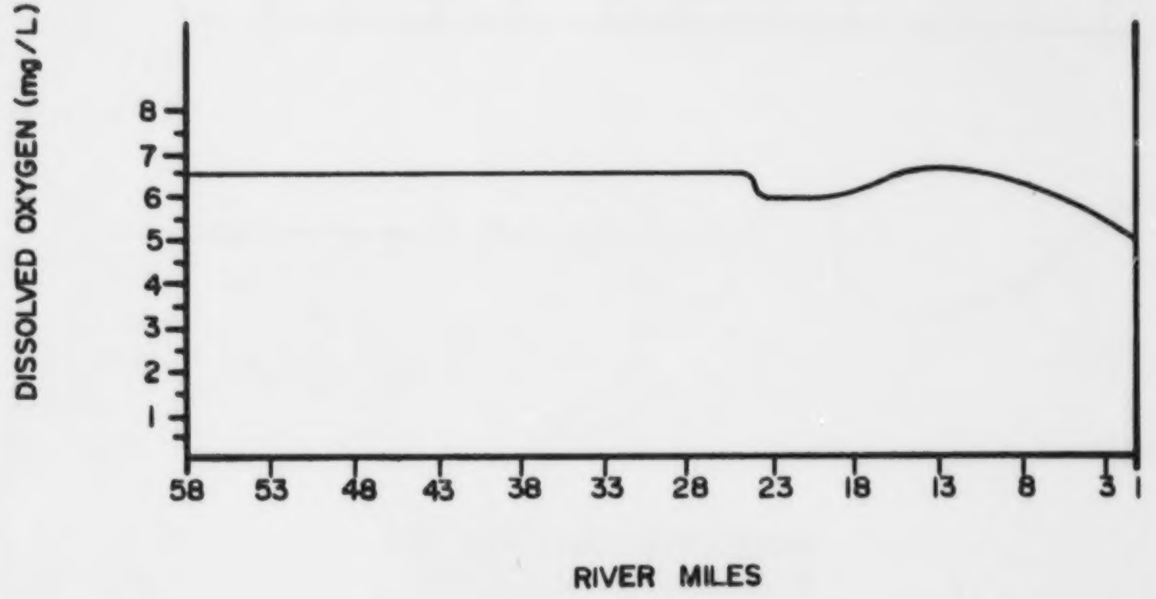
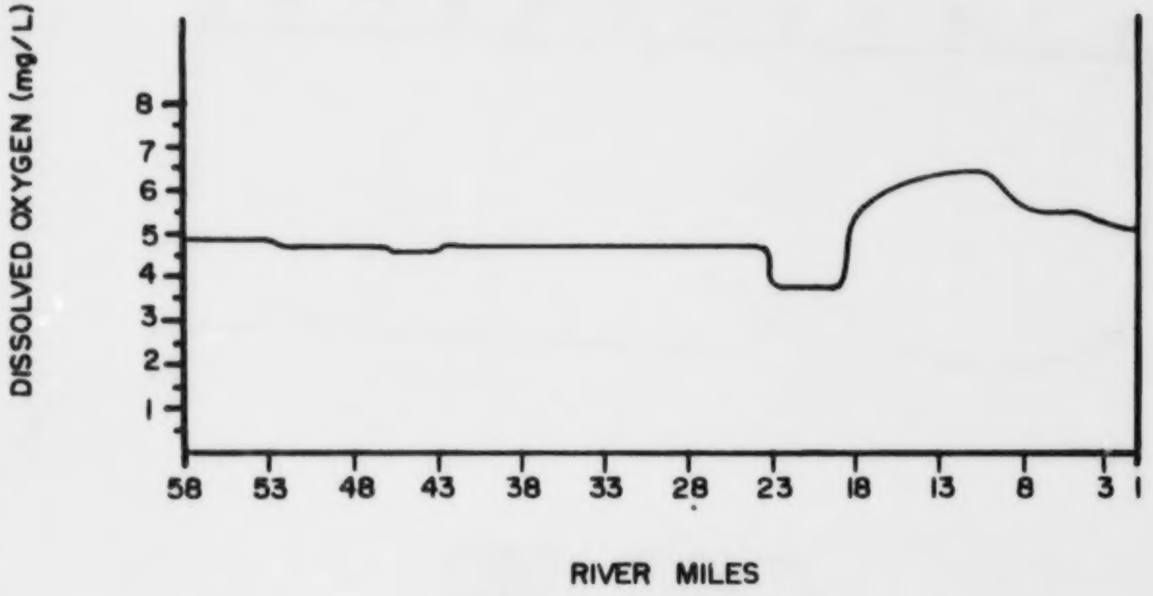


FIGURE III-28
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 5 CONCEPT B
NO BENTHIC REDUCTION



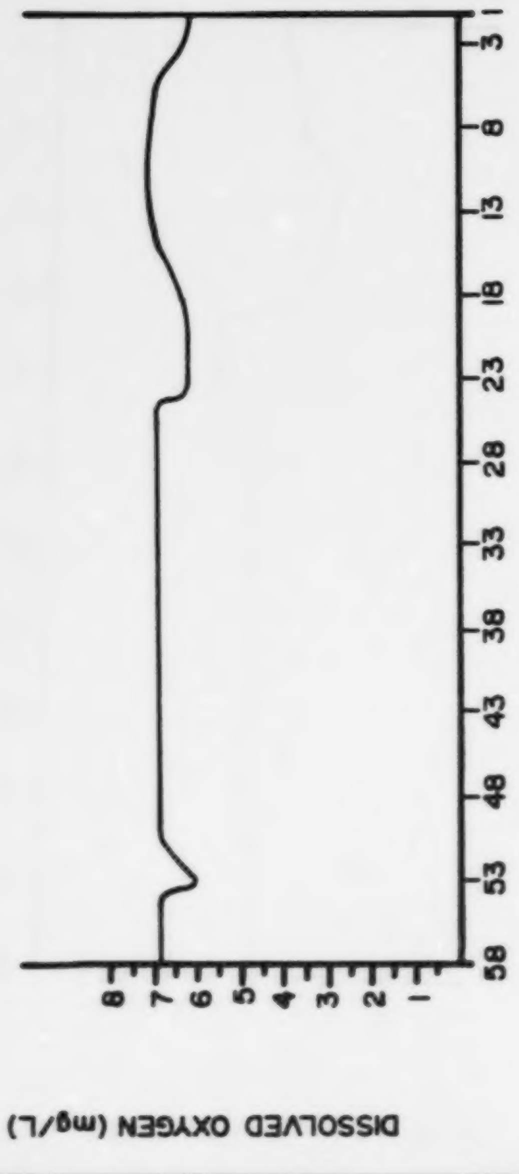


FIGURE III - 29
CYPRESS CREEK
DISSOLVED OXYGEN PROFILE
THEME 5 CONCEPT B
BENTHIC REDUCTION

FIGURE III-30
CYPRESS CREEK
5 DAYS 24 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

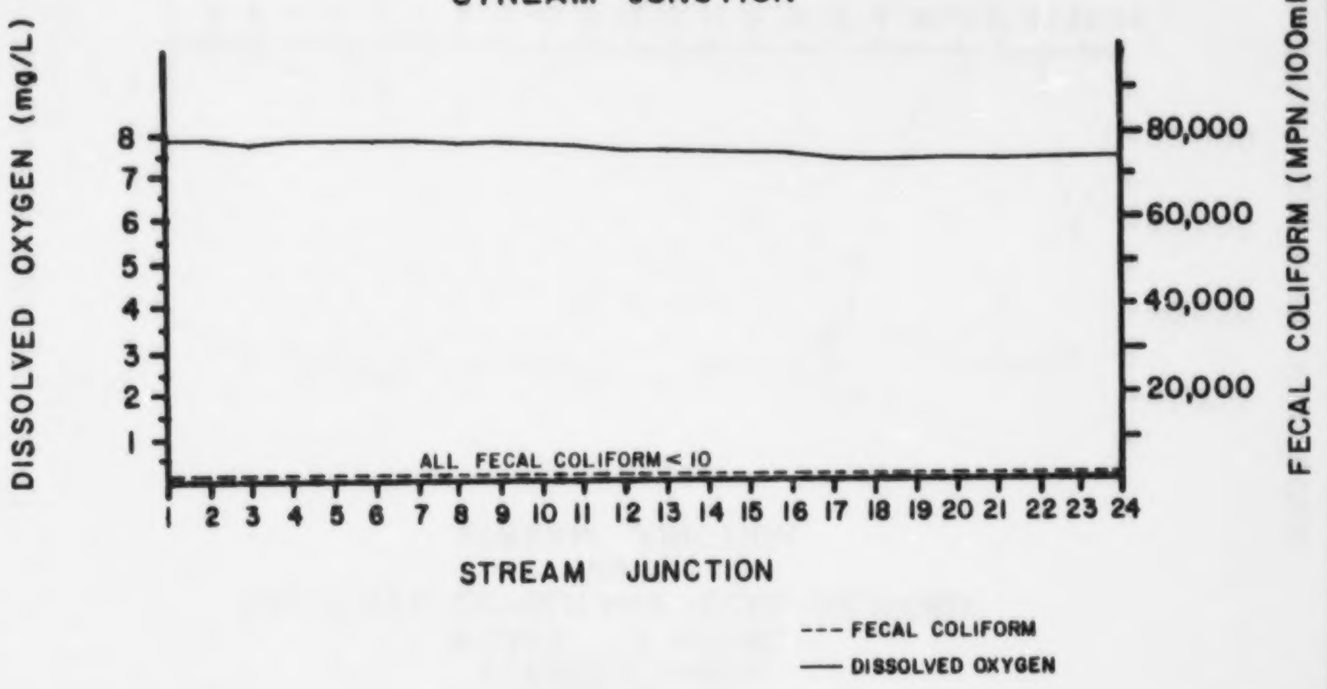
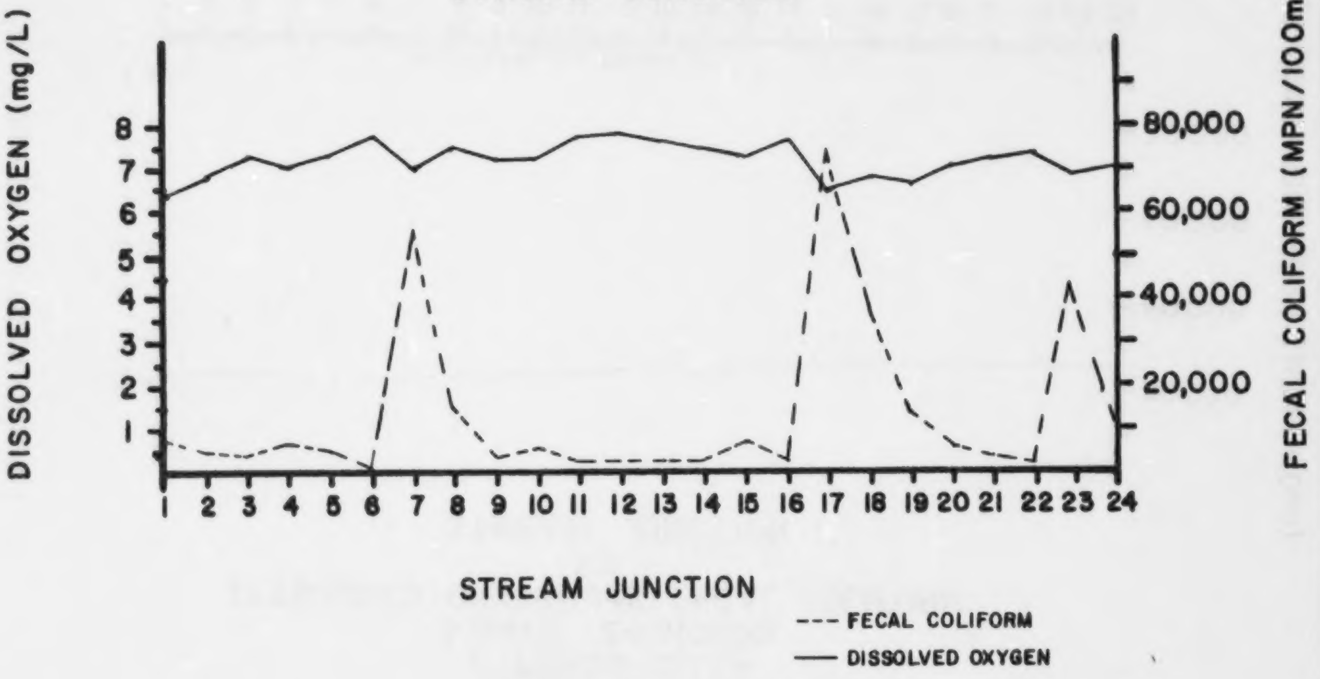


FIGURE III - 31
CYPRESS CREEK
6 DAYS 2 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION



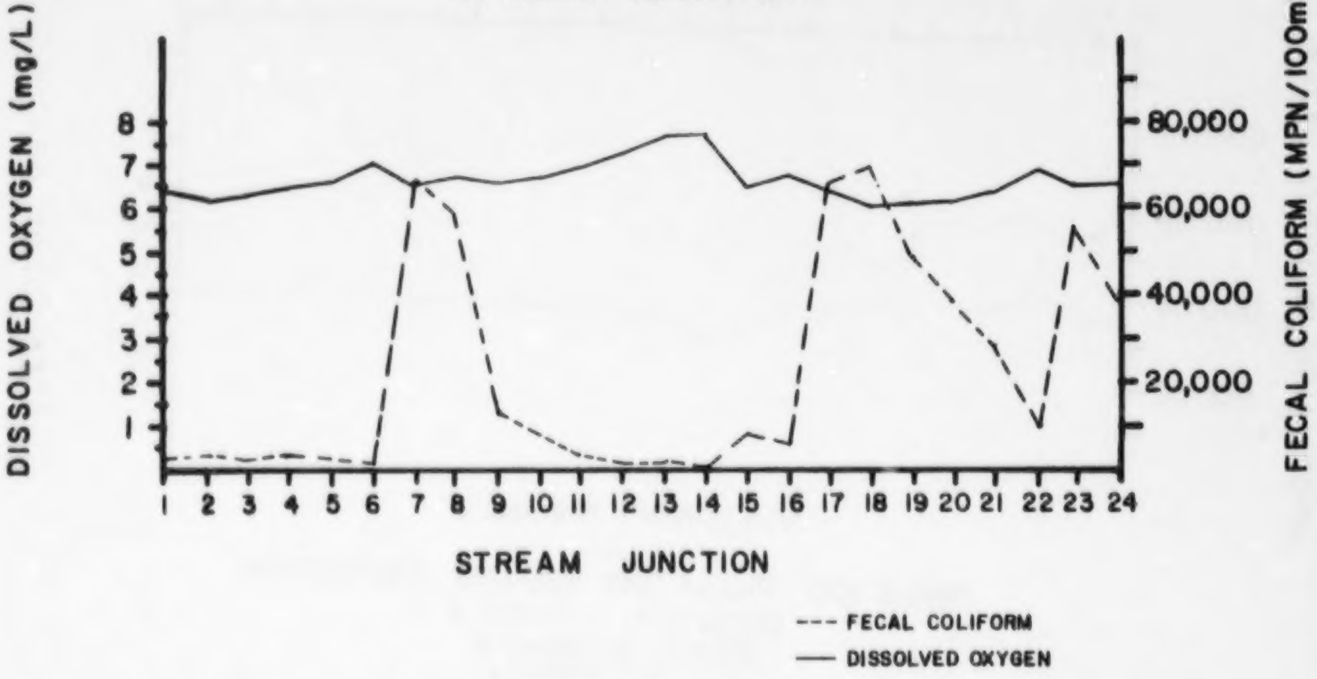


FIGURE III - 32
CYPRESS CREEK
6 DAYS 4 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

FIGURE III-33
CYPRESS CREEK
6 DAYS 6 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

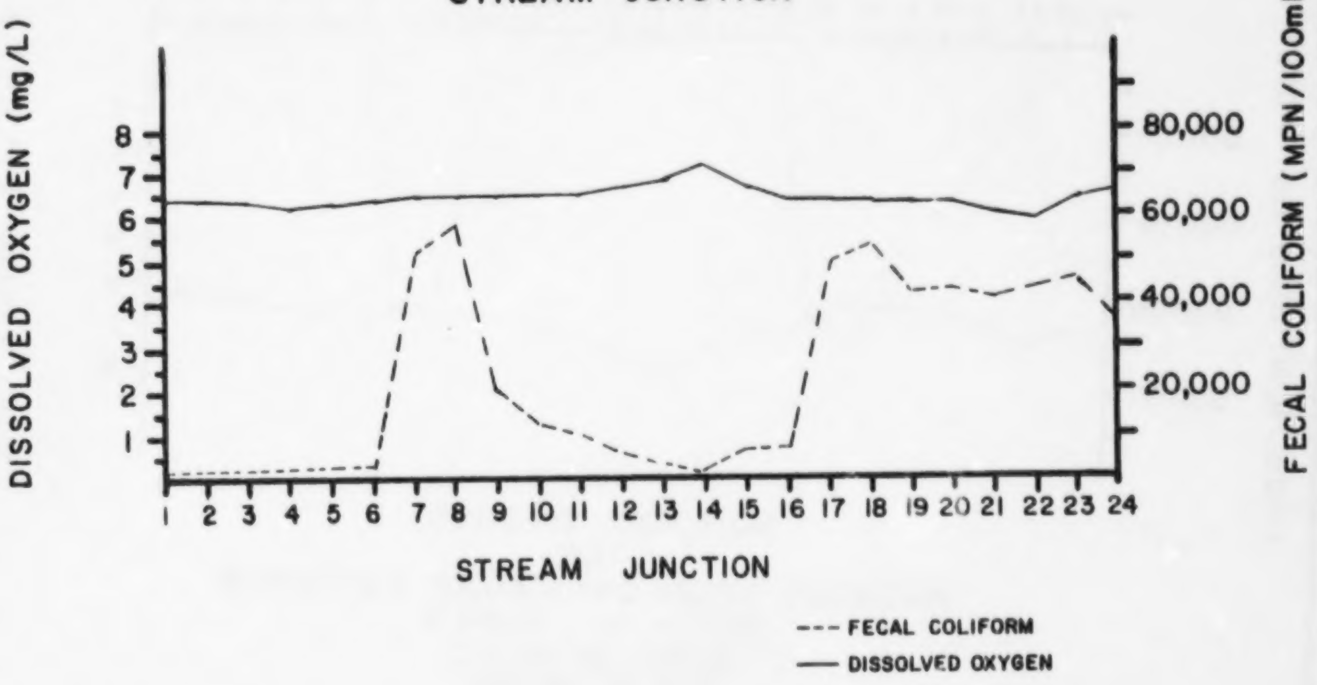


FIGURE III - 34
CYPRESS CREEK
6 DAYS 8 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

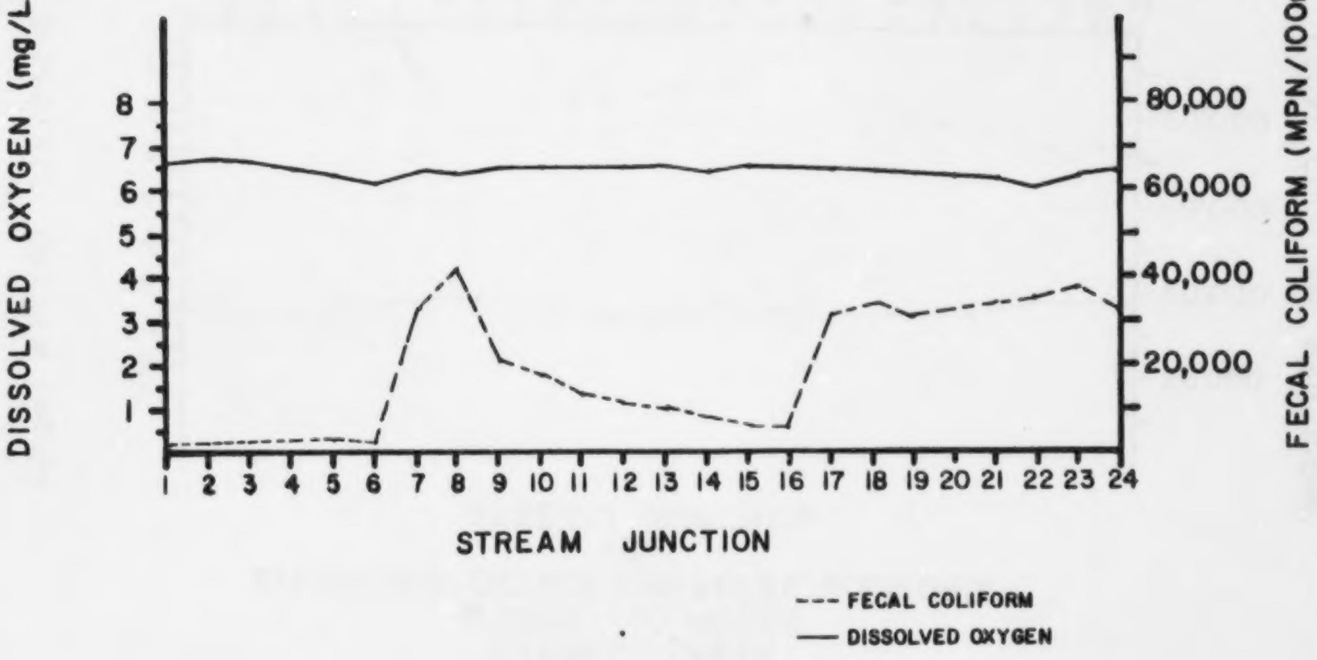


FIGURE III - 35
CYPRESS CREEK
6 DAYS 10 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

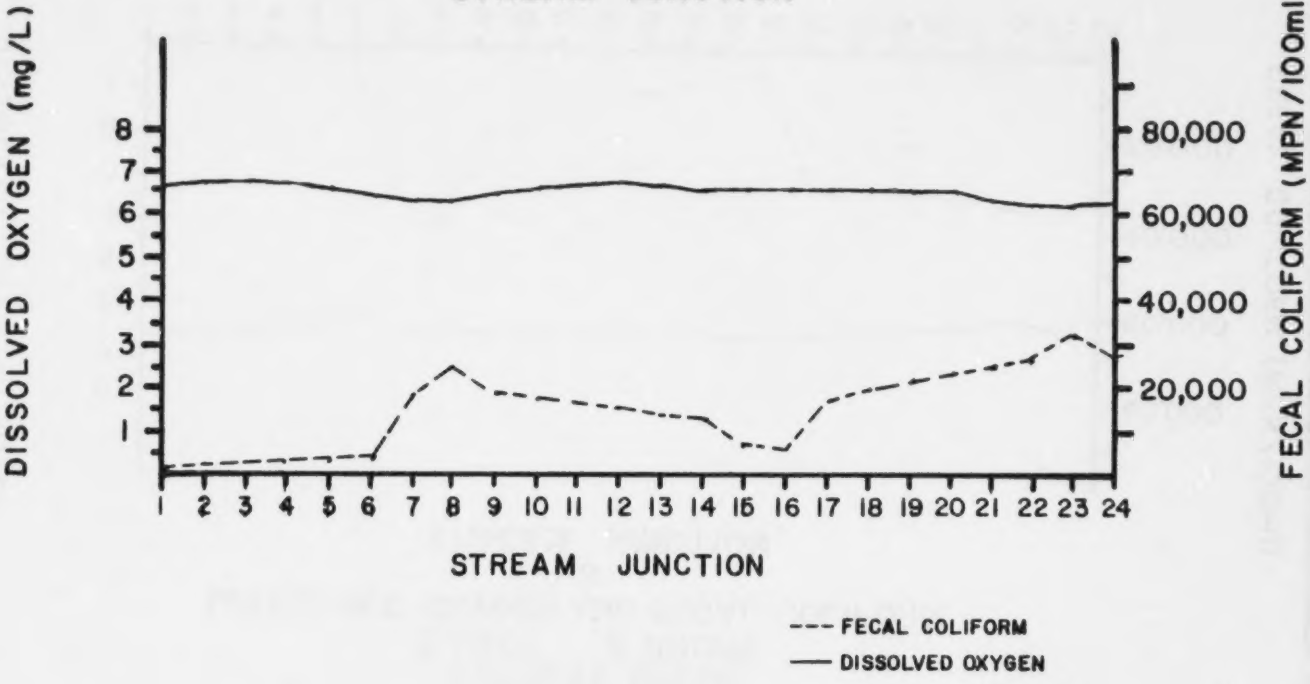


FIGURE III - 36
CYPRESS CREEK
6 DAYS 12 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

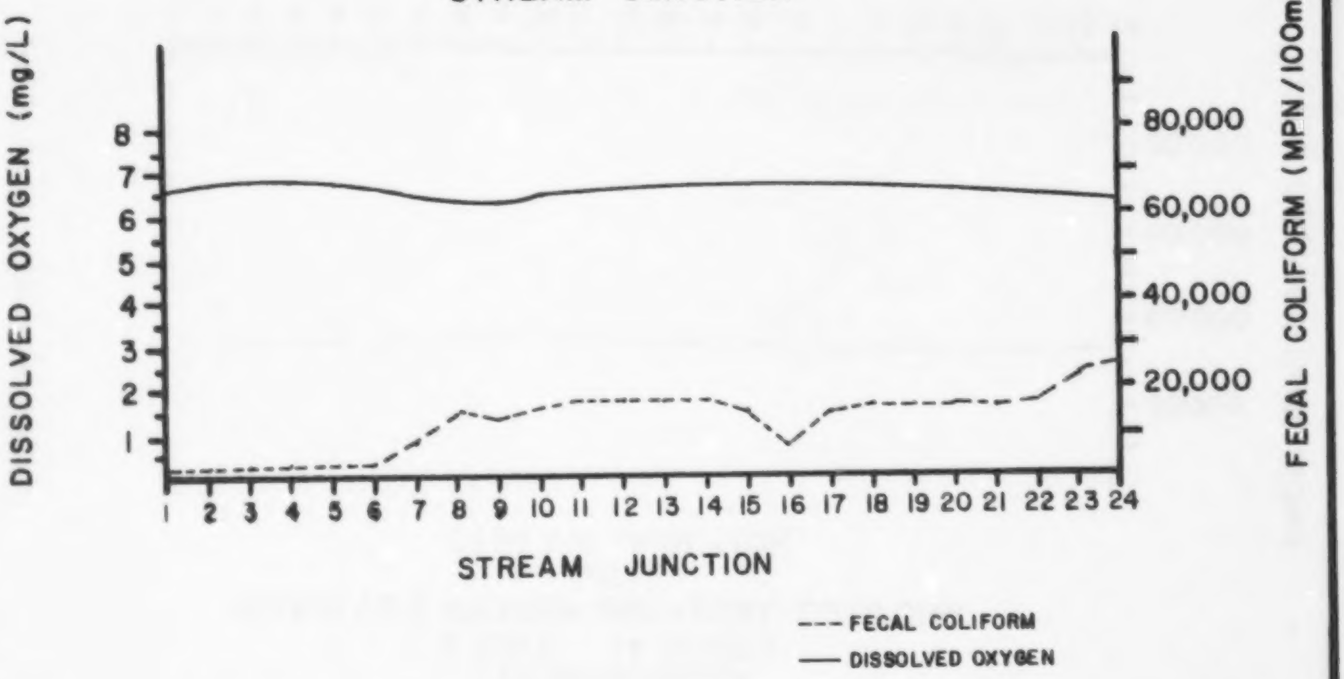


FIGURE III - 37
CYPRESS CREEK
6 DAYS 14 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

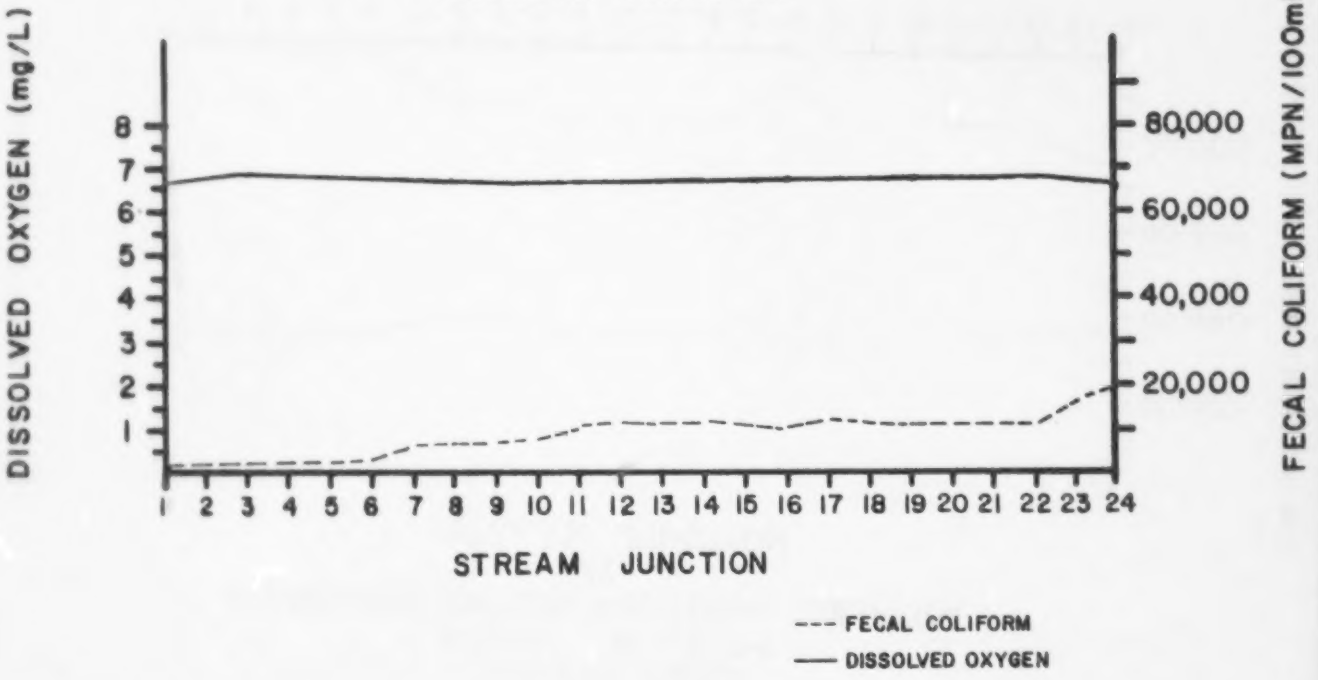


FIGURE III – 38
CYPRESS CREEK
6 DAYS 16 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

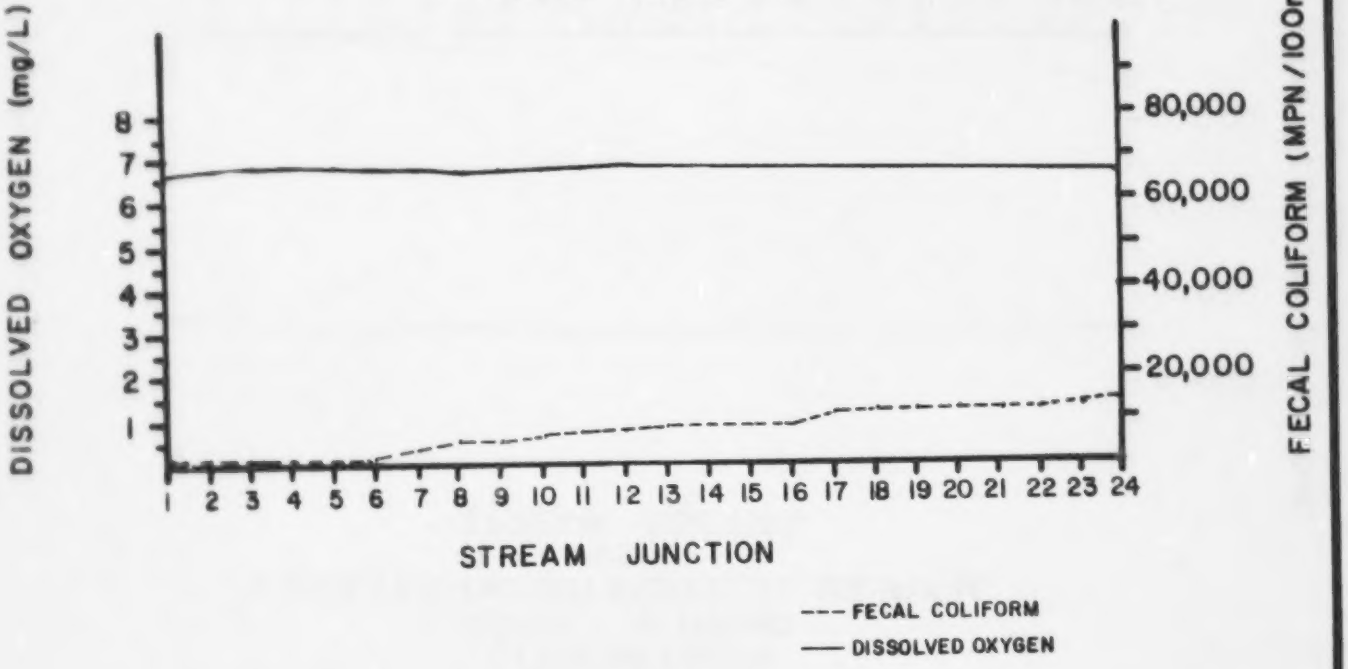


FIGURE III-39
CYPRESS CREEK
6 DAYS 18 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

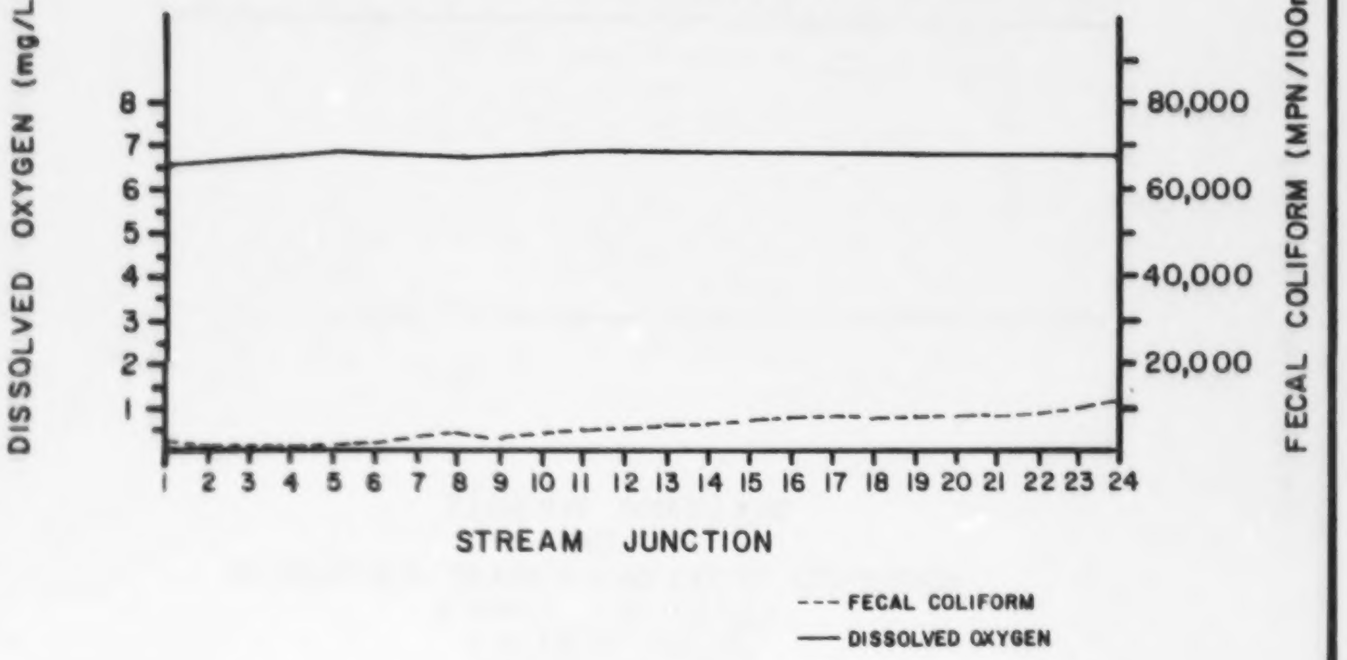


FIGURE III - 40
CYPRESS CREEK
6 DAYS 20 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

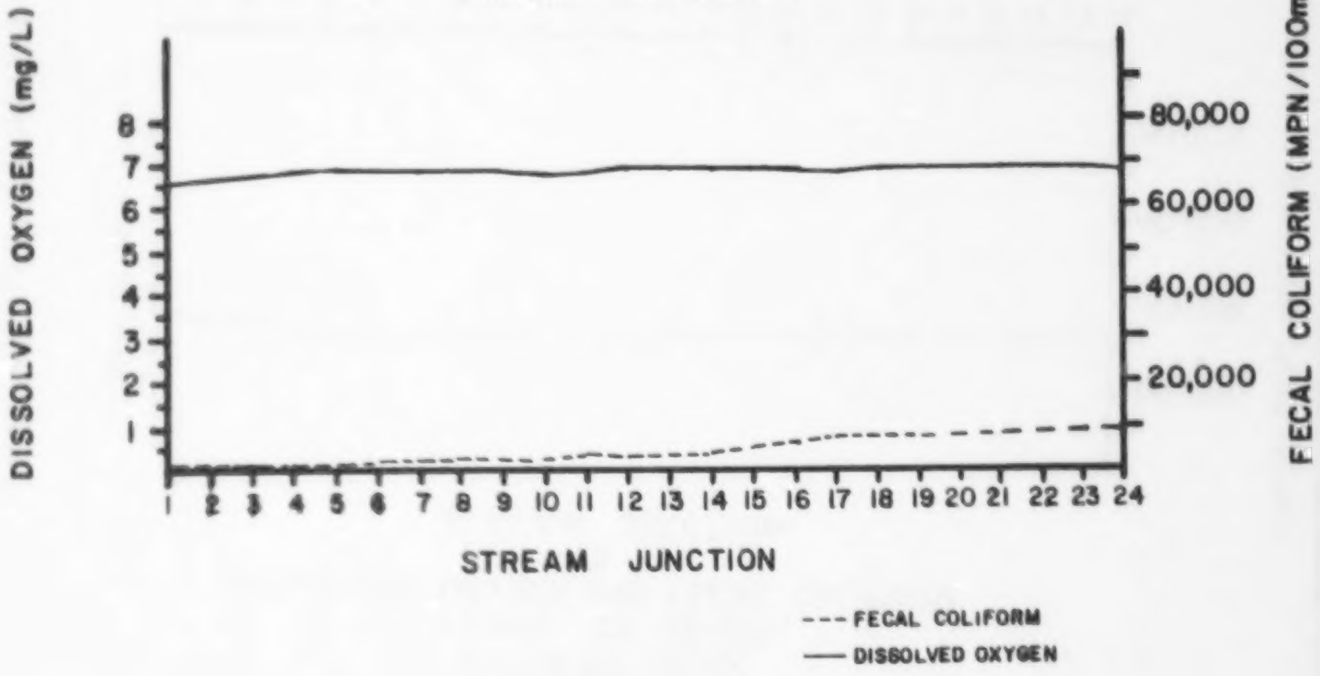


FIGURE III - 41
CYPRESS CREEK
6 DAYS 22 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

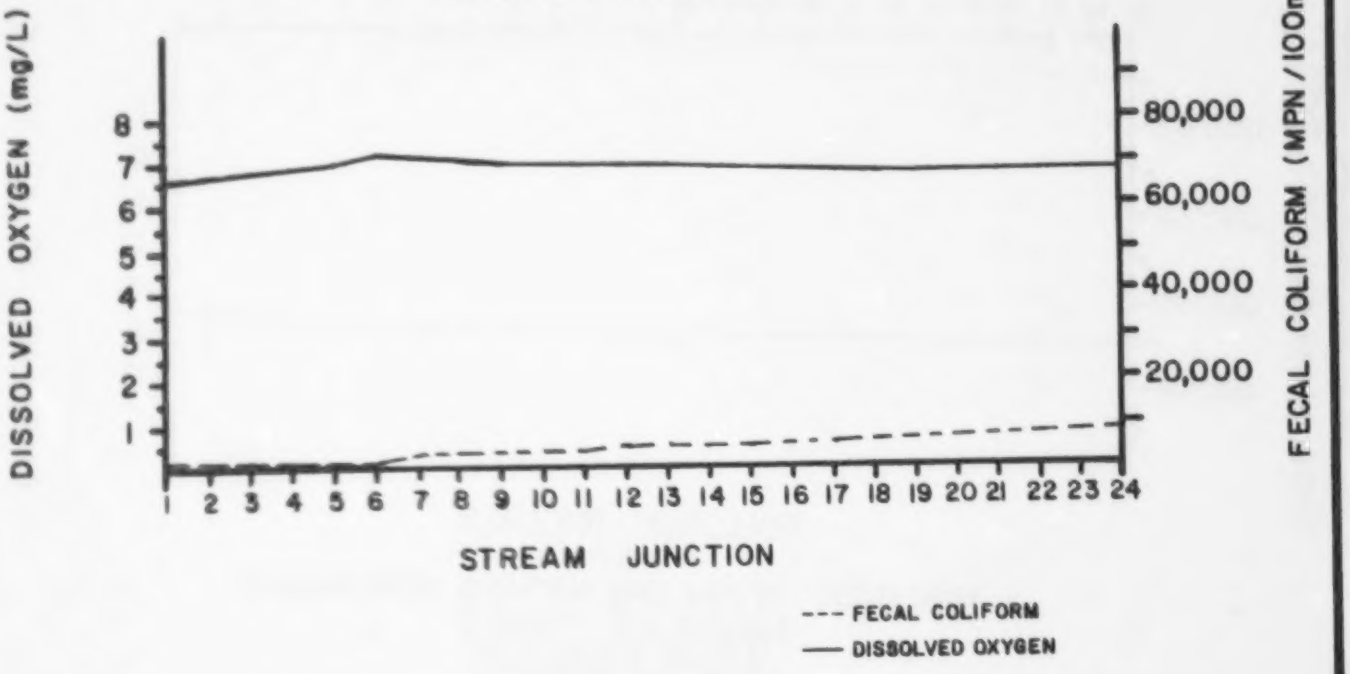


FIGURE III - 42
CYPRESS CREEK
6 DAYS 24 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

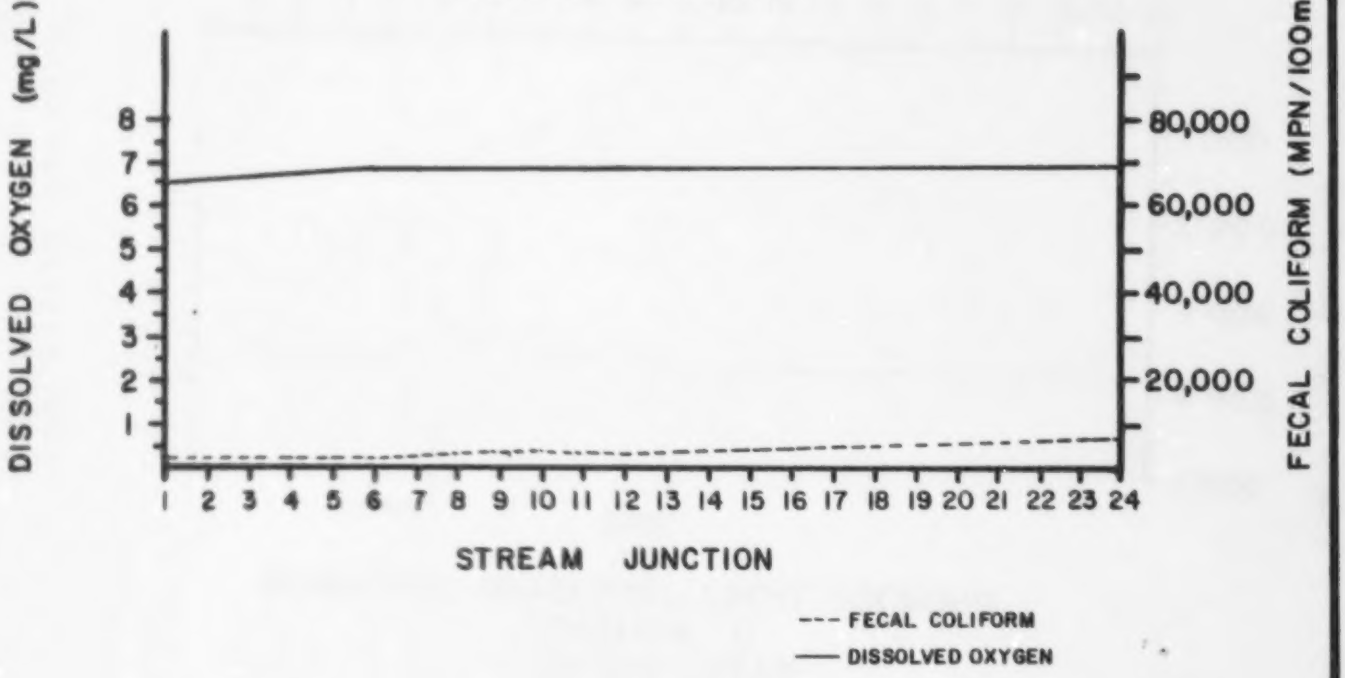


FIGURE III-43
CYPRESS CREEK
JUNCTION 17
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
TIME

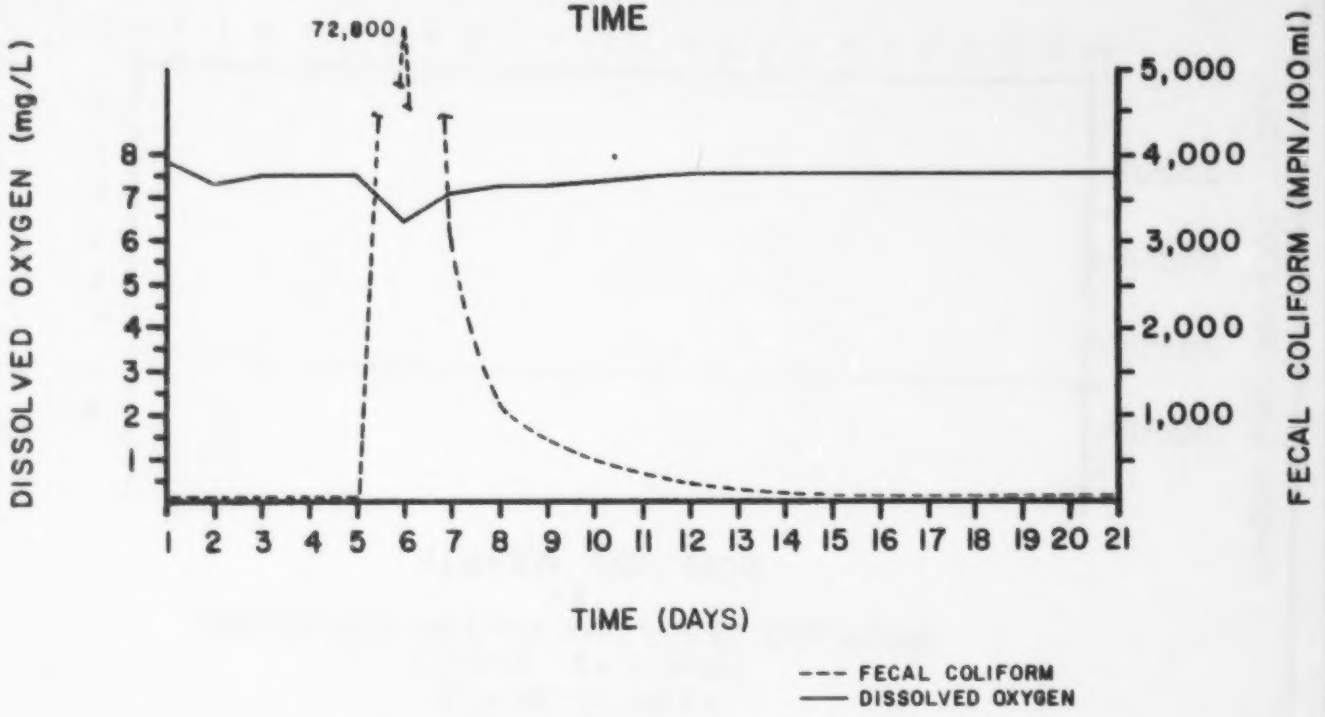


FIGURE IV - 1
CLEAR CREEK - NONTIDAL
DISSOLVED OXYGEN PROFILE
BASELINE

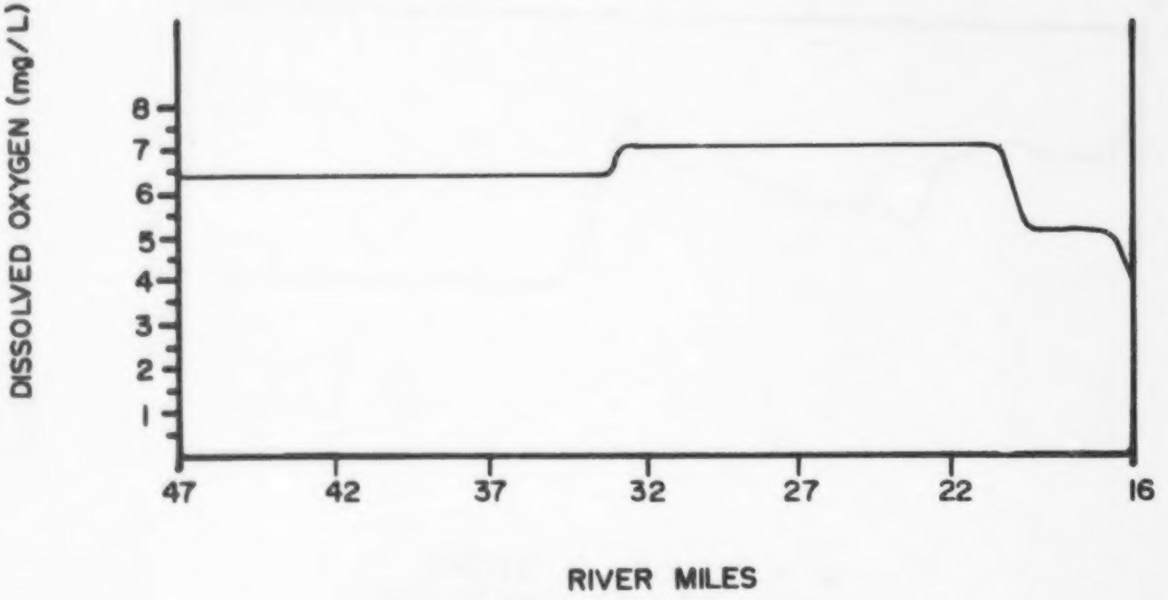


FIGURE IV - 2
CLEAR CREEK - NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

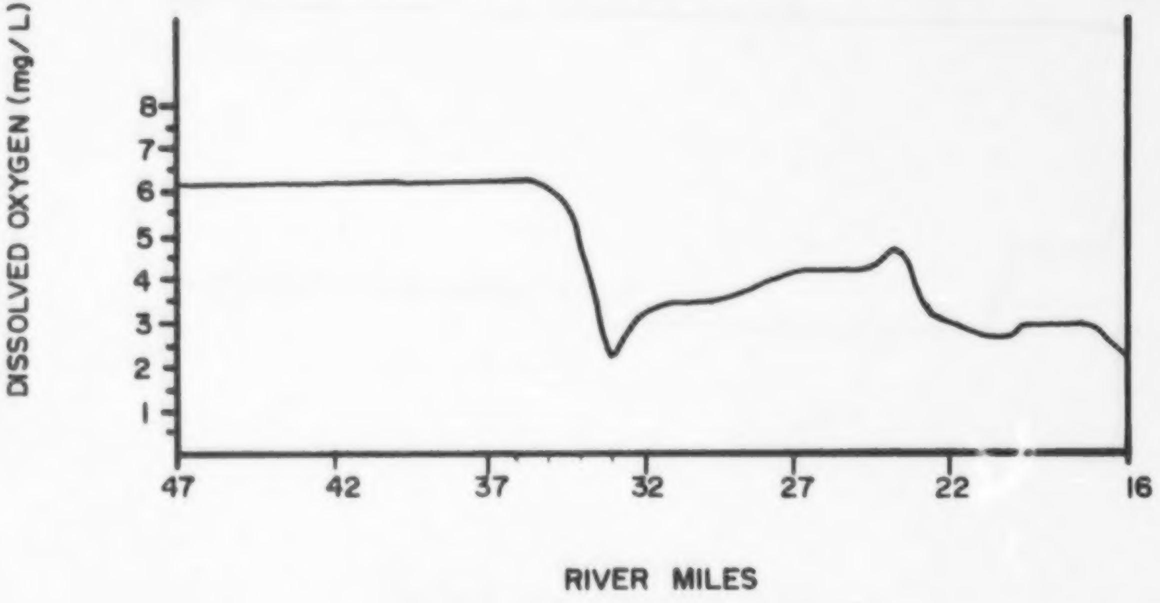


FIGURE IV - 3
CLEAR CREEK - NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

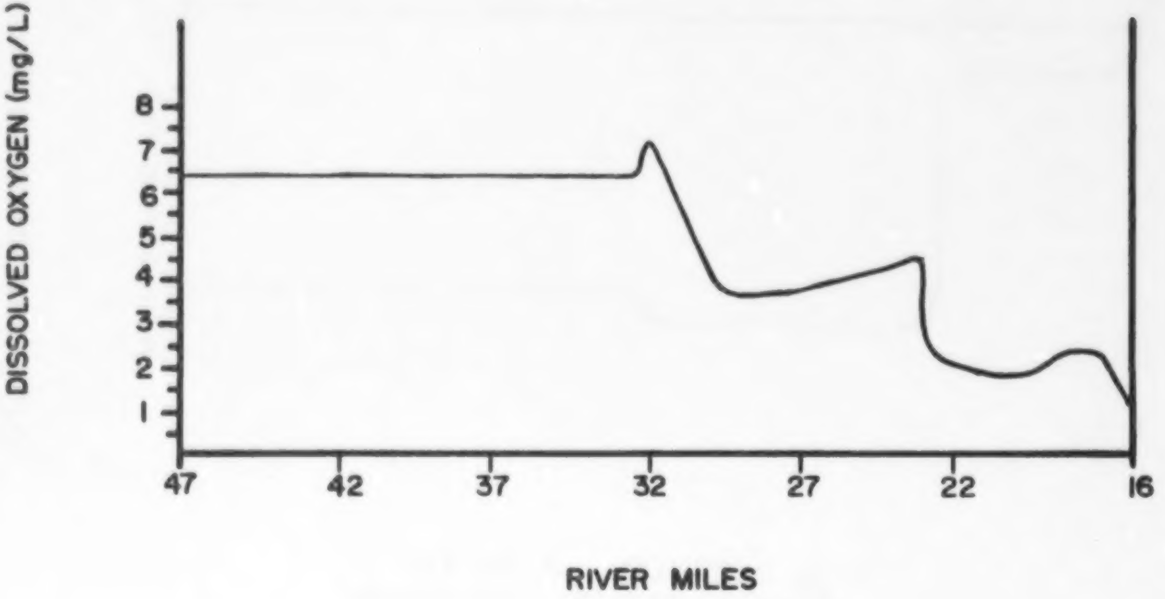


FIGURE IV-4
CLEAR CREEK-NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

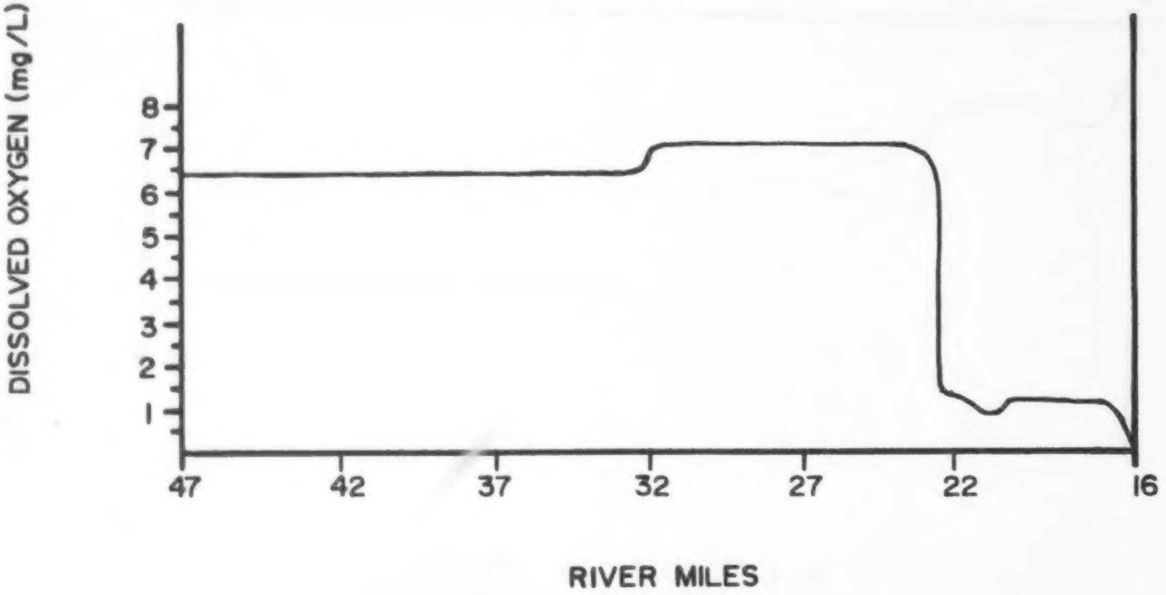


FIGURE IV - 5
CLEAR CREEK-NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A
NO BENTHIC REDUCTION

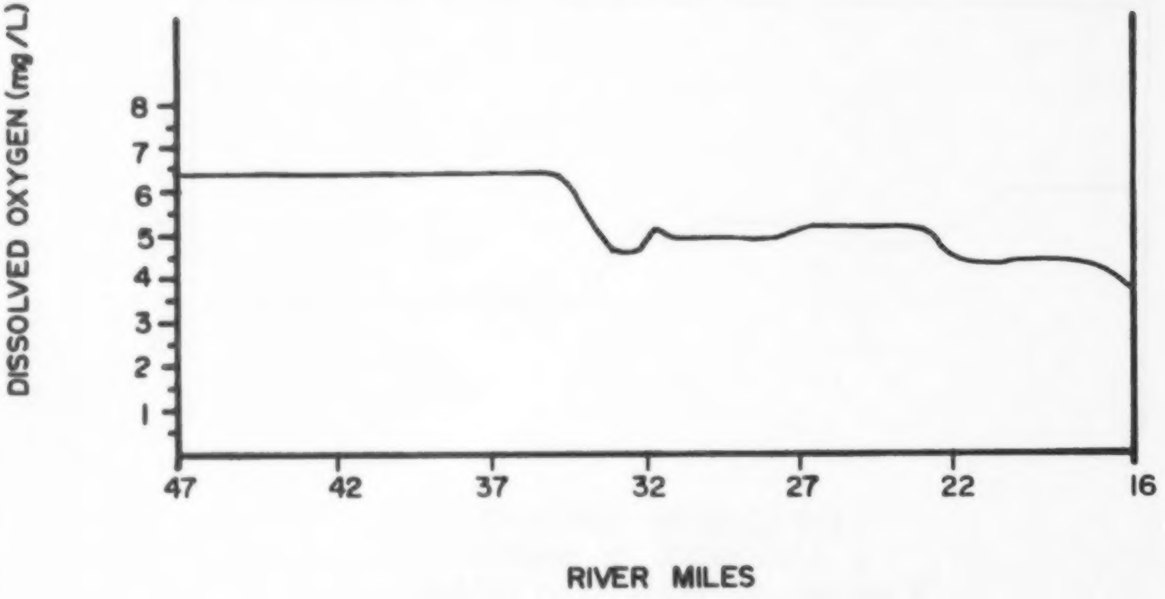


FIGURE IV - 6
CLEAR CREEK - NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A
BENTHIC REDUCTION

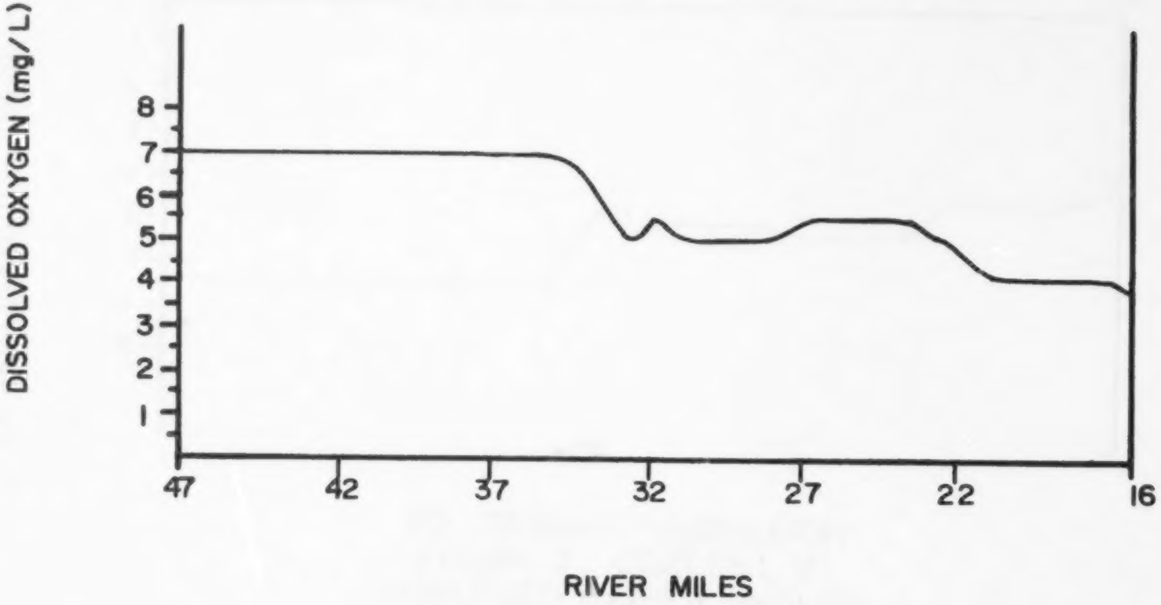


FIGURE IV - 7
CLEAR CREEK - NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT B
BENTHIC REDUCTION

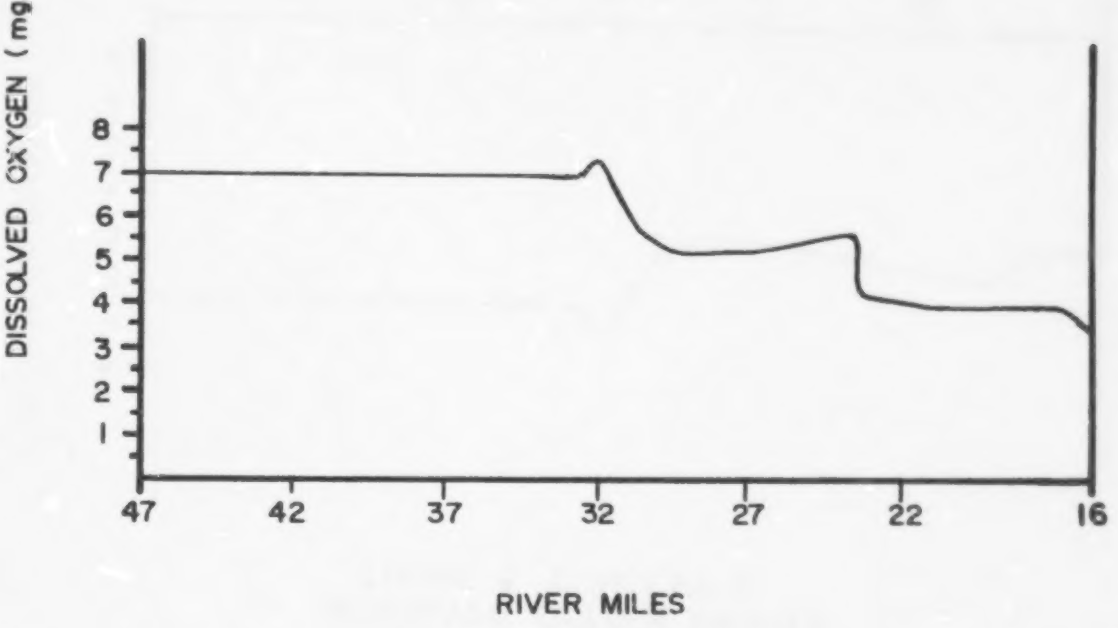


FIGURE IV-8
CLEAR CREEK-NONTIDAL
DISSOLVED OXYGEN PROFILE
THEME 5 CONCEPT B

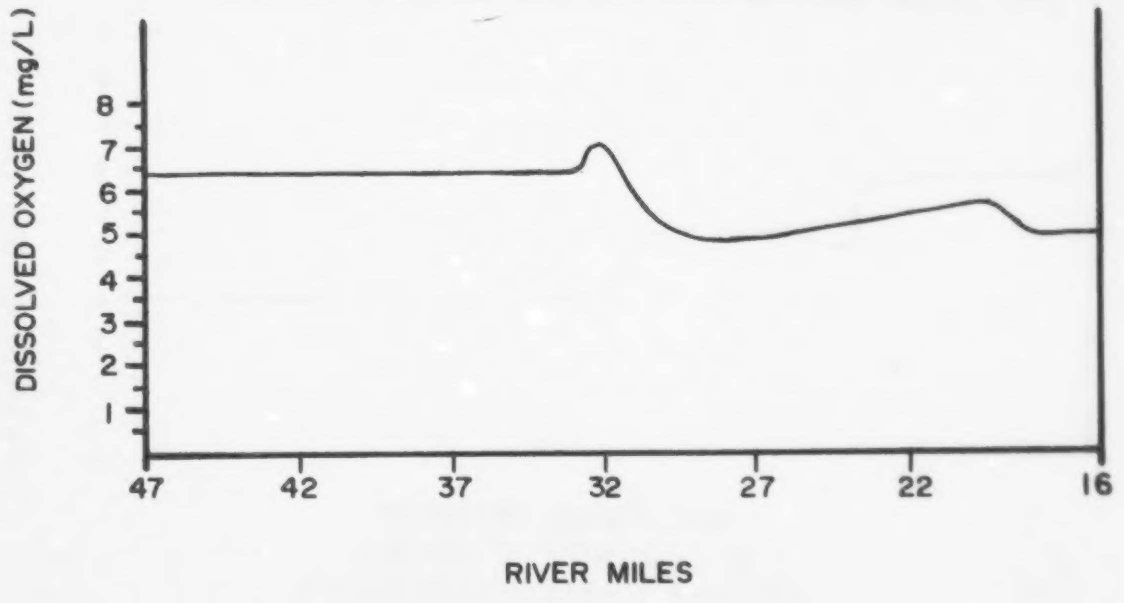


FIGURE IV - 9
CLEAR CREEK
5 DAYS 24 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

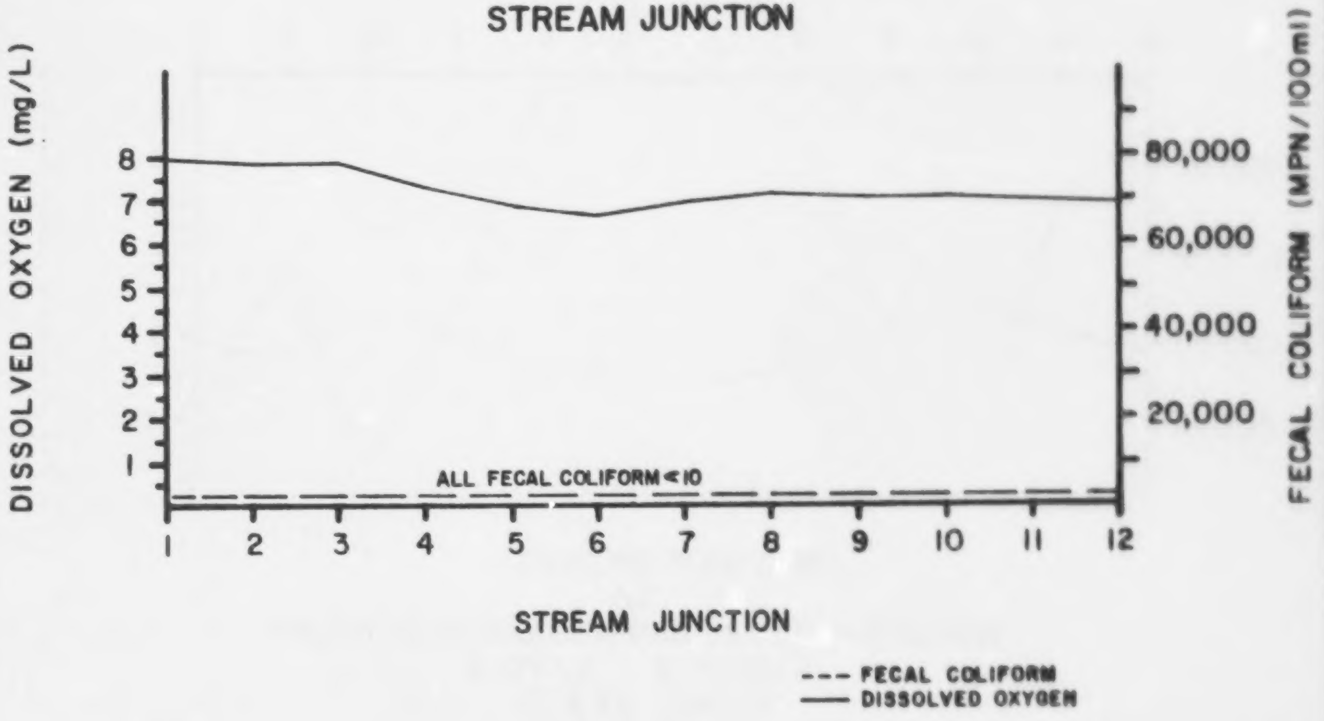


FIGURE IV-10
CLEAR CREEK
6 DAYS 2 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

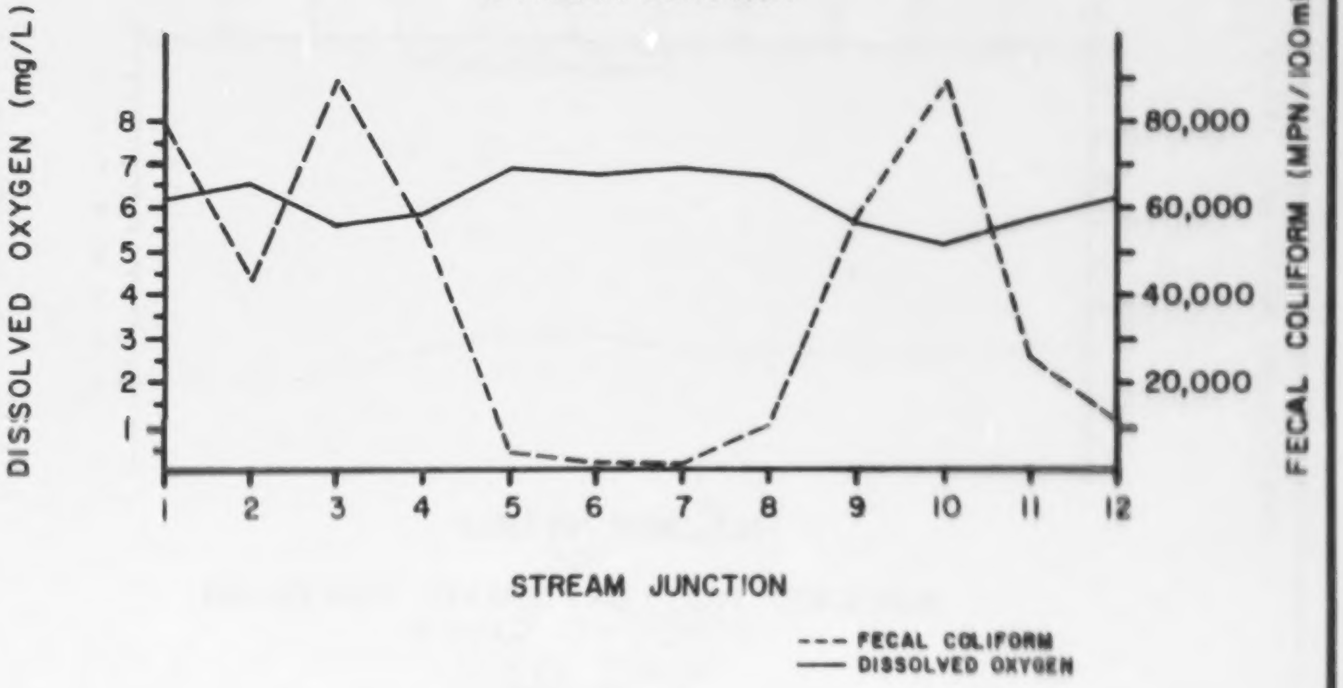


FIGURE IV-11
CLEAR CREEK
6 DAYS 6 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

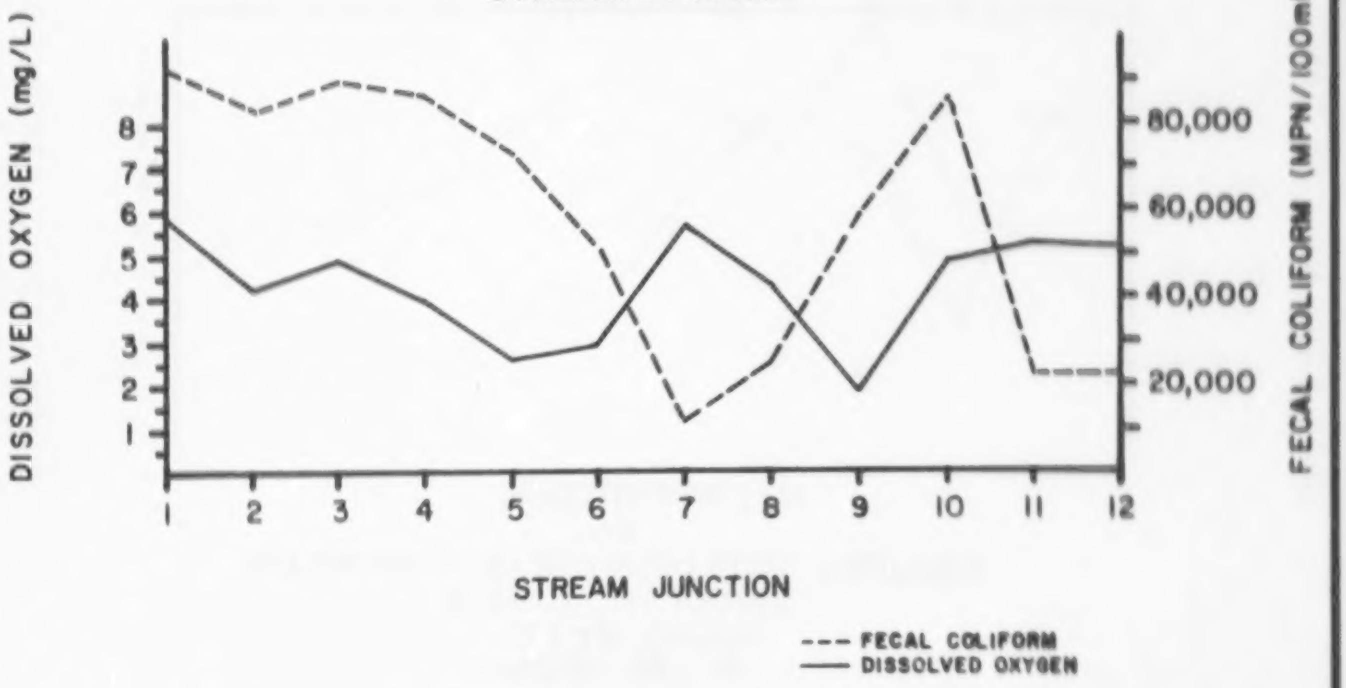


FIGURE IV-12
CLEAR CREEK
6 DAYS 10 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

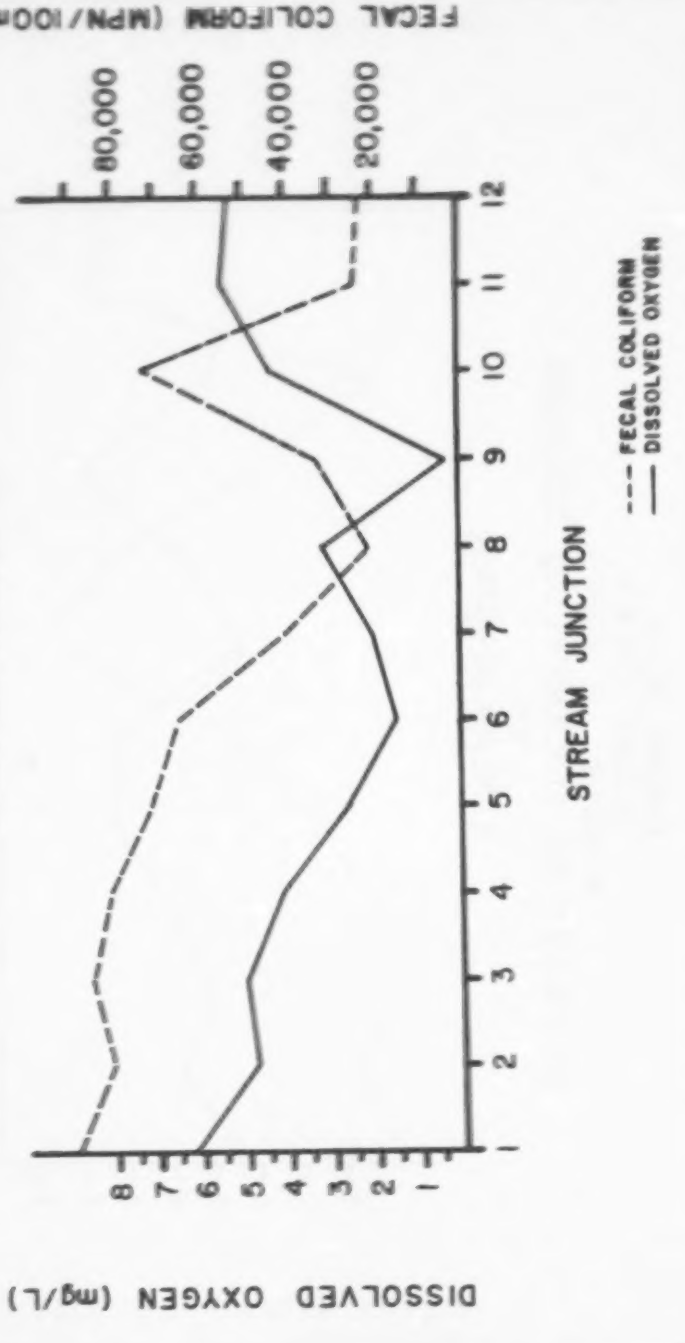


FIGURE IV-13
CLEAR CREEK
6 DAYS 14 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

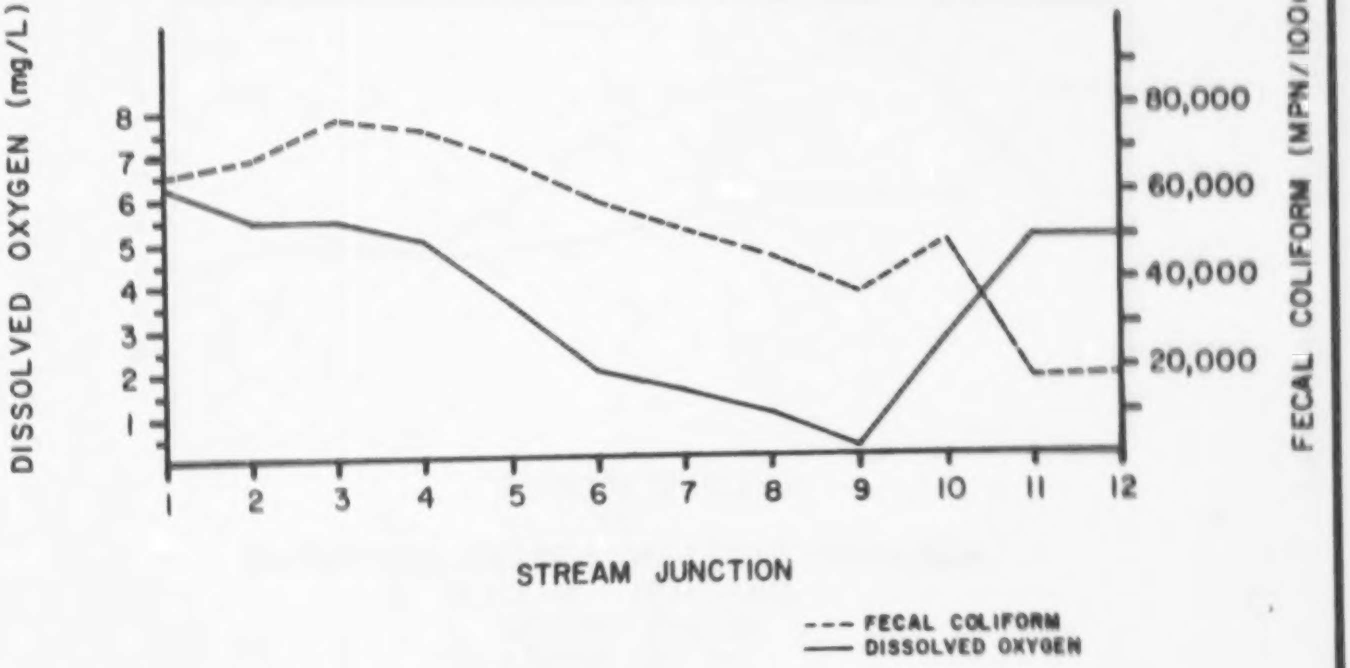


FIGURE IV - 14
CLEAR CREEK
6 DAYS 18 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

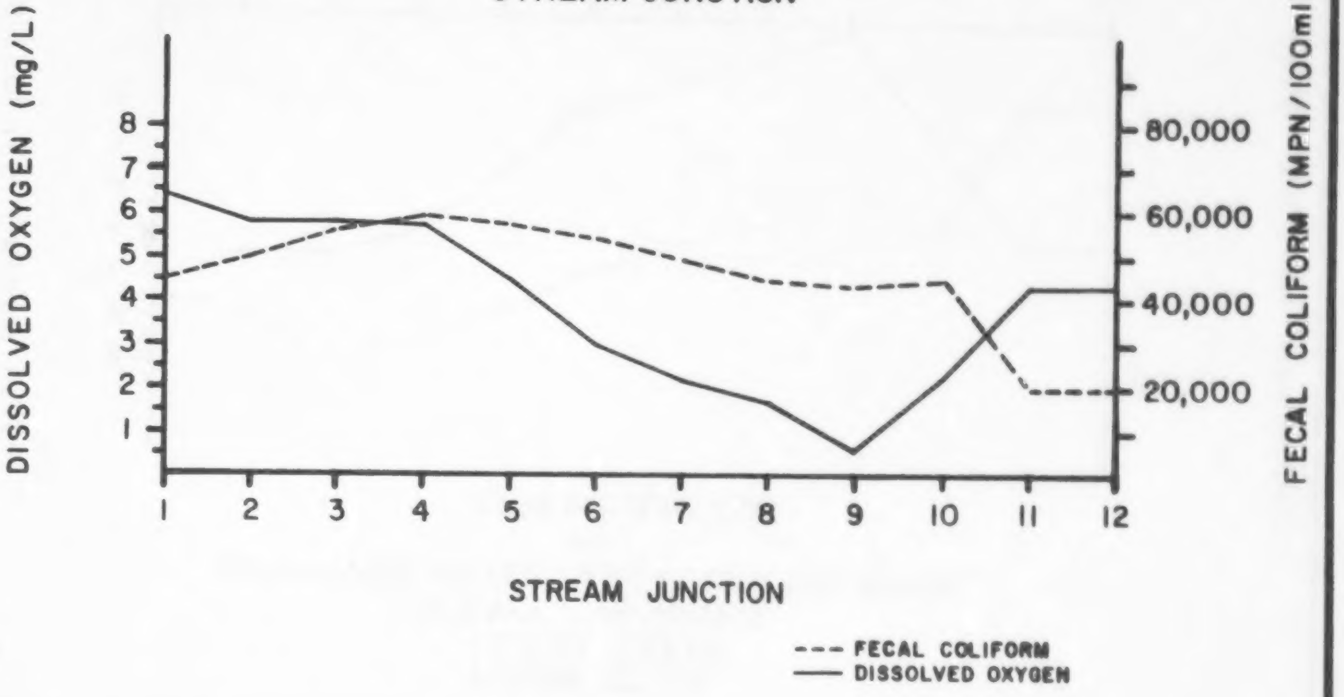


FIGURE IV- 15
CLEAR CREEK
6 DAYS 22 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

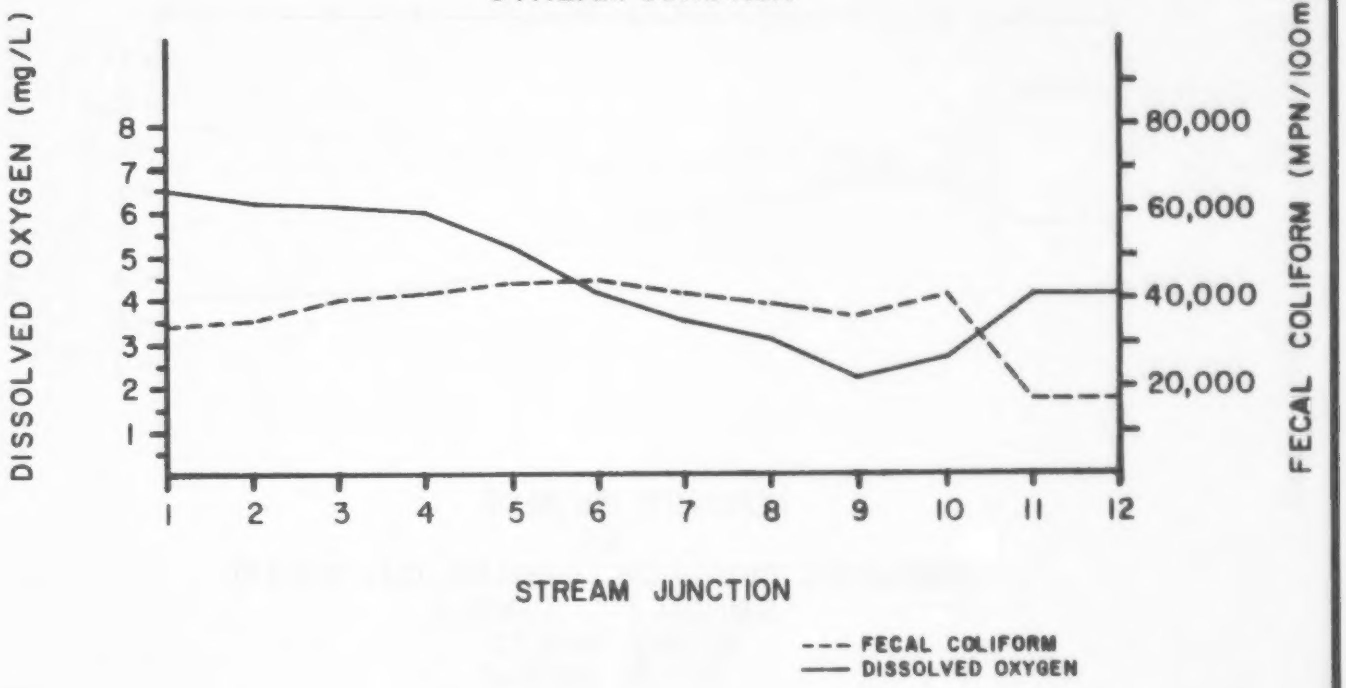


FIGURE IV-16
CLEAR CREEK
7 DAYS 2 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

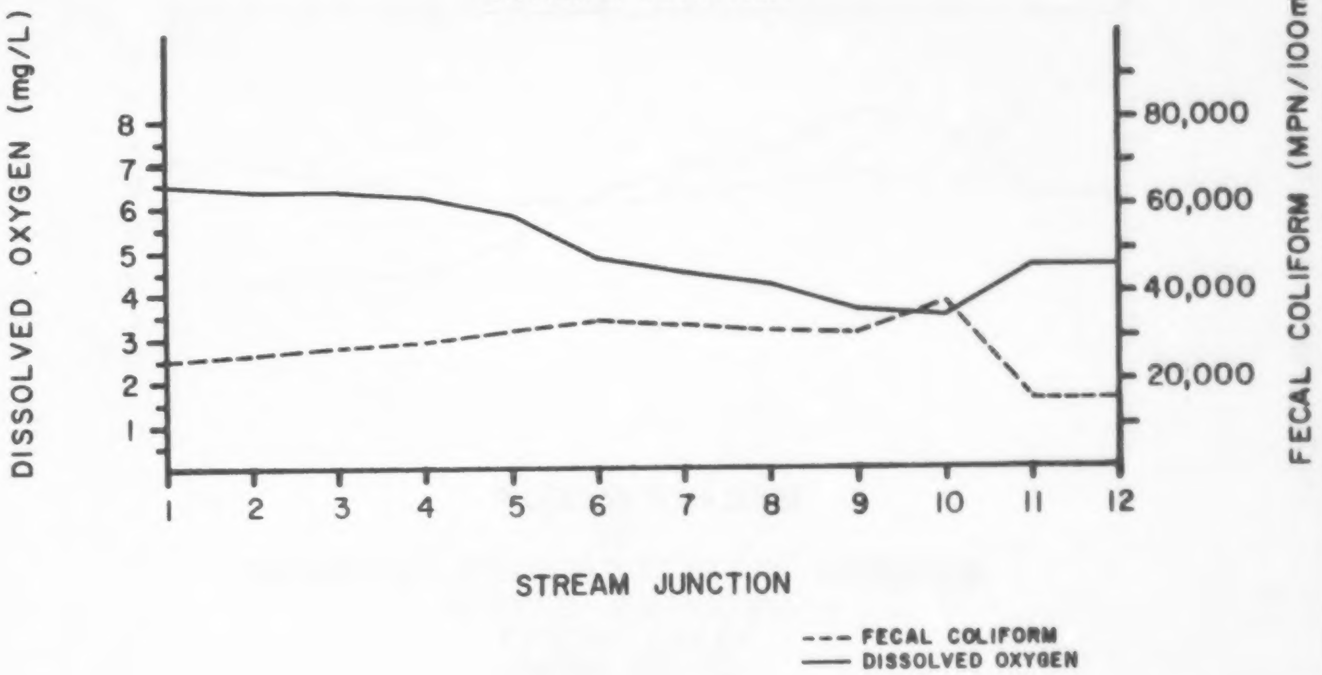


FIGURE IV-17
CLEAR CREEK
7 DAYS 6 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

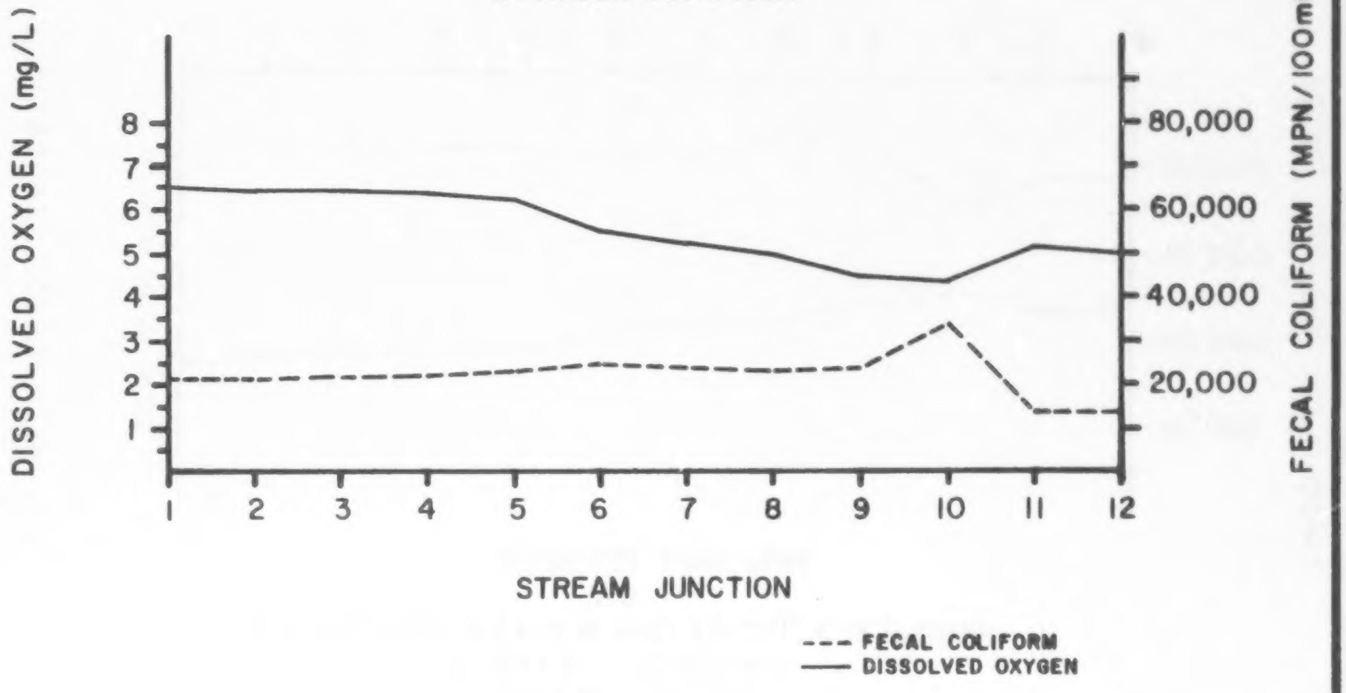


FIGURE IV-18
CLEAR CREEK
7 DAYS 10 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

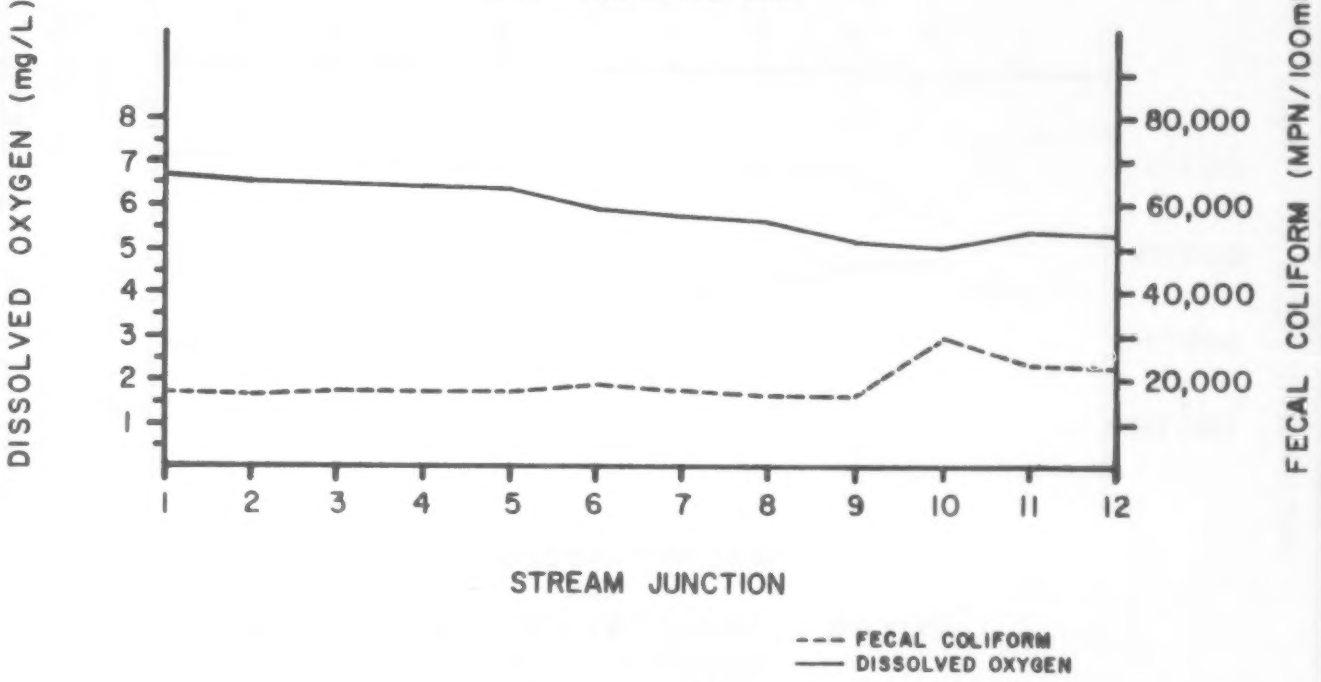


FIGURE IV-19
CLEAR CREEK
7 DAYS 14 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

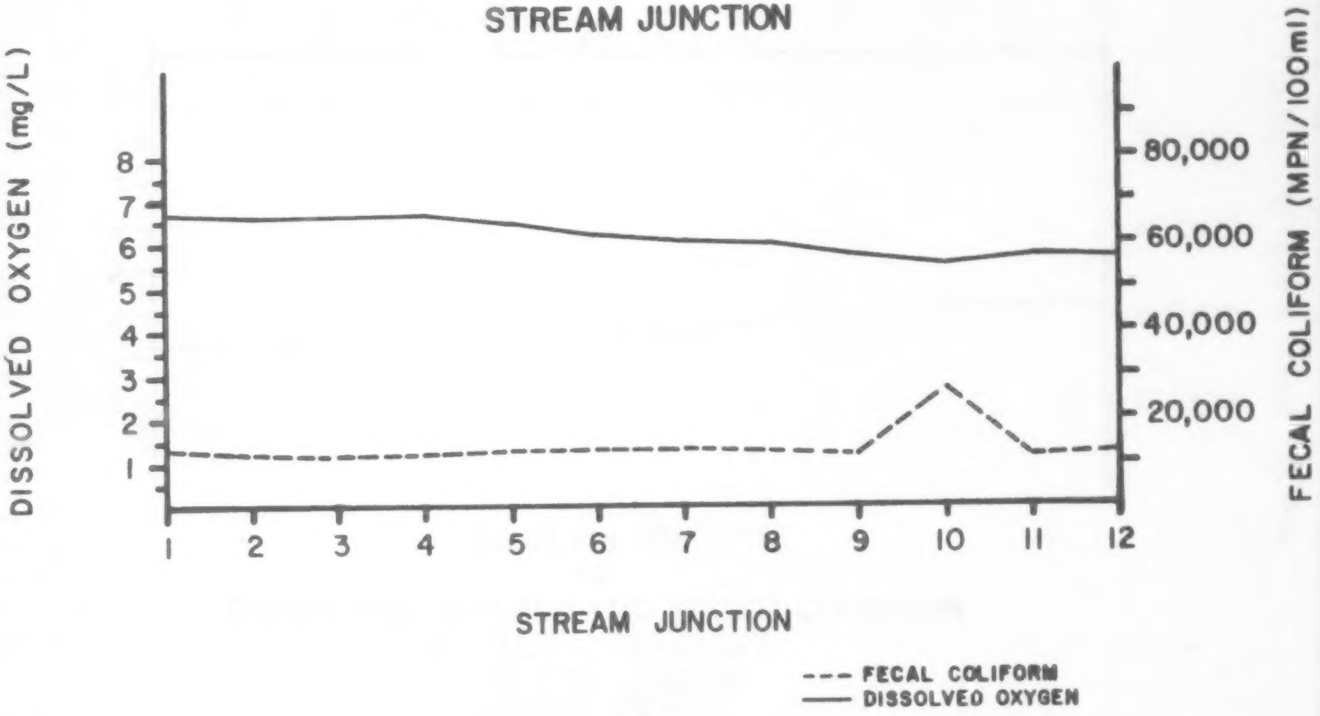


FIGURE IV-20
CLEAR CREEK
7 DAYS 18 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

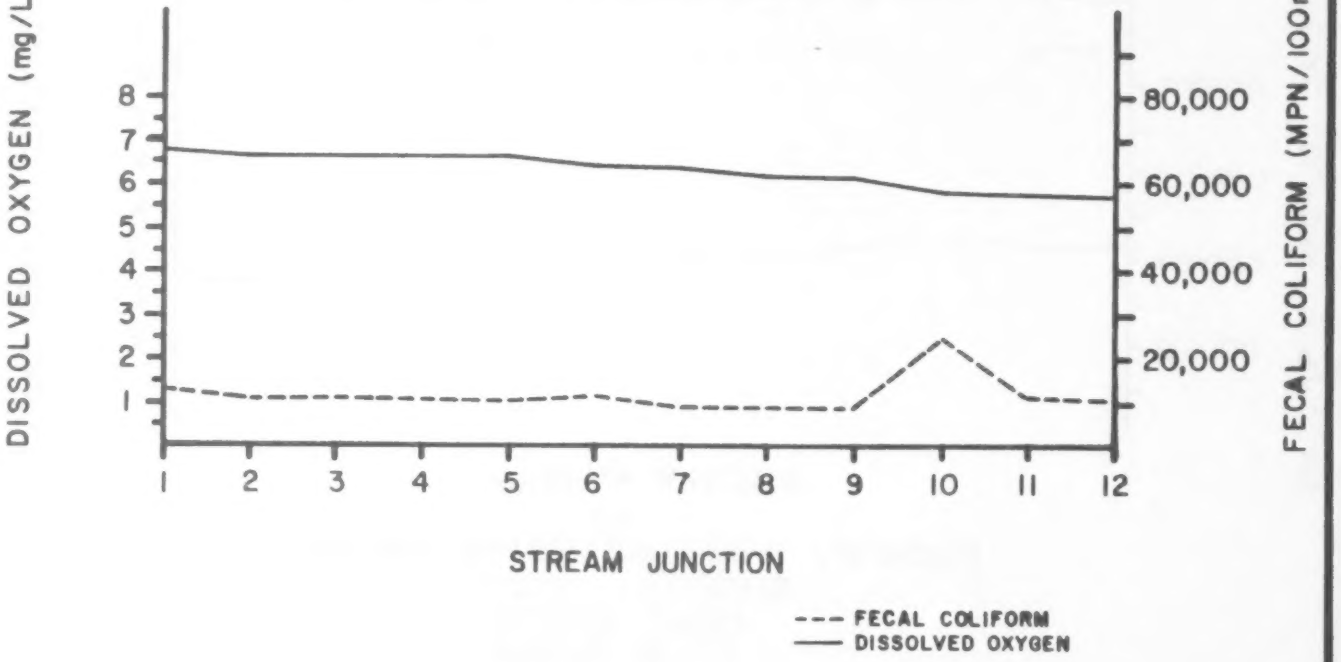


FIGURE IV- 21
CLEAR CREEK
7 DAYS 22 HOURS
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

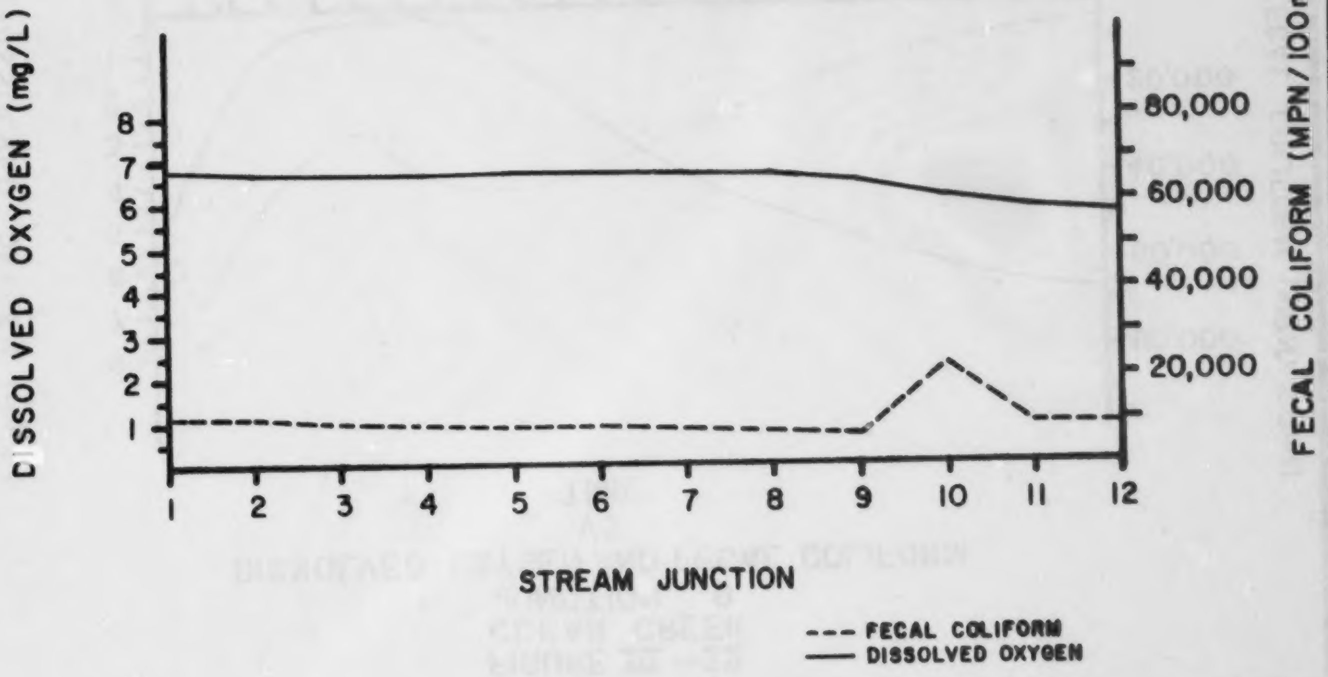


FIGURE IV - 22
CLEAR CREEK
JUNCTION 9
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
TIME

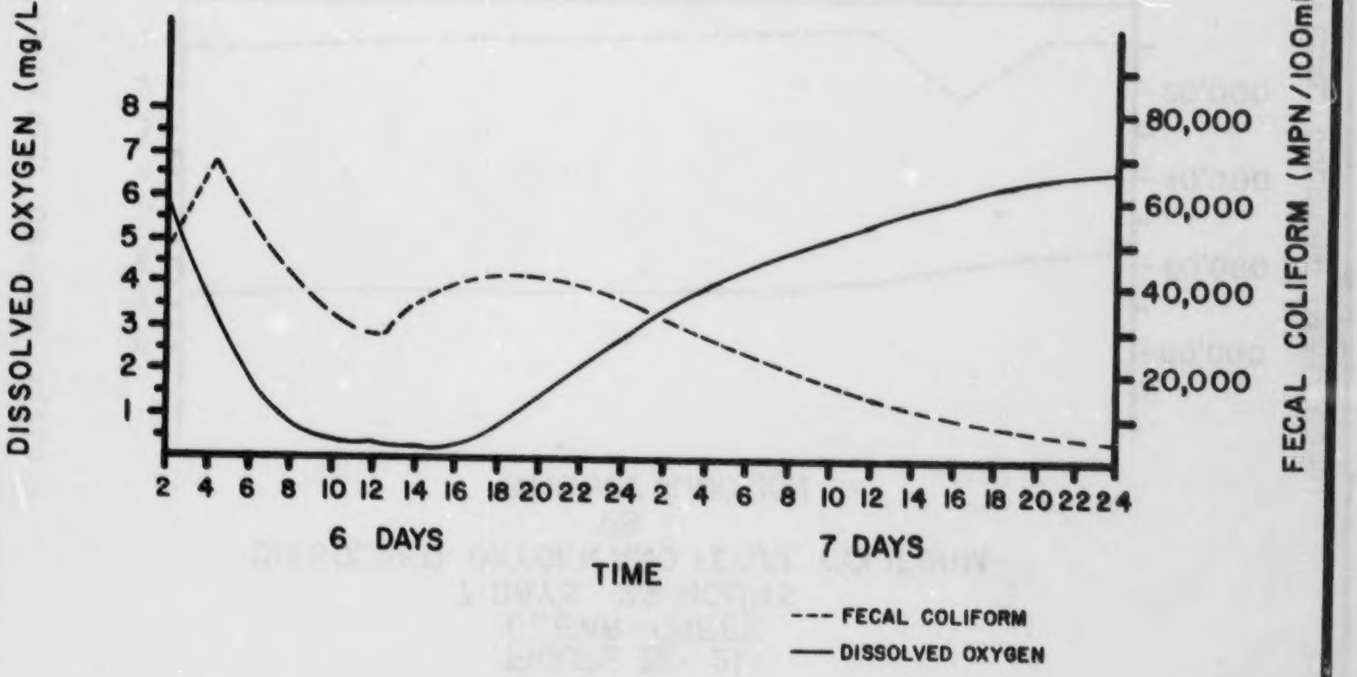


FIGURE IV- 23
CLEAR CREEK
JUNCTION 10
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
TIME

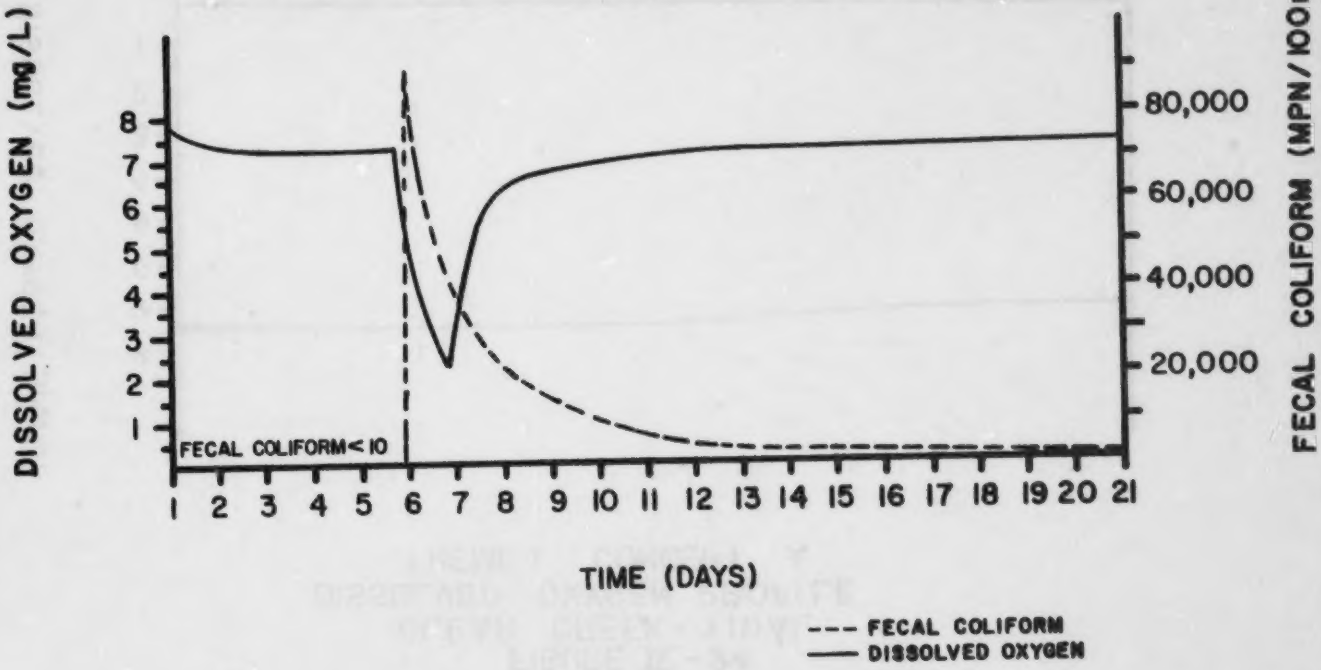


FIGURE IV-24
CLEAR CREEK- TIDAL
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT A

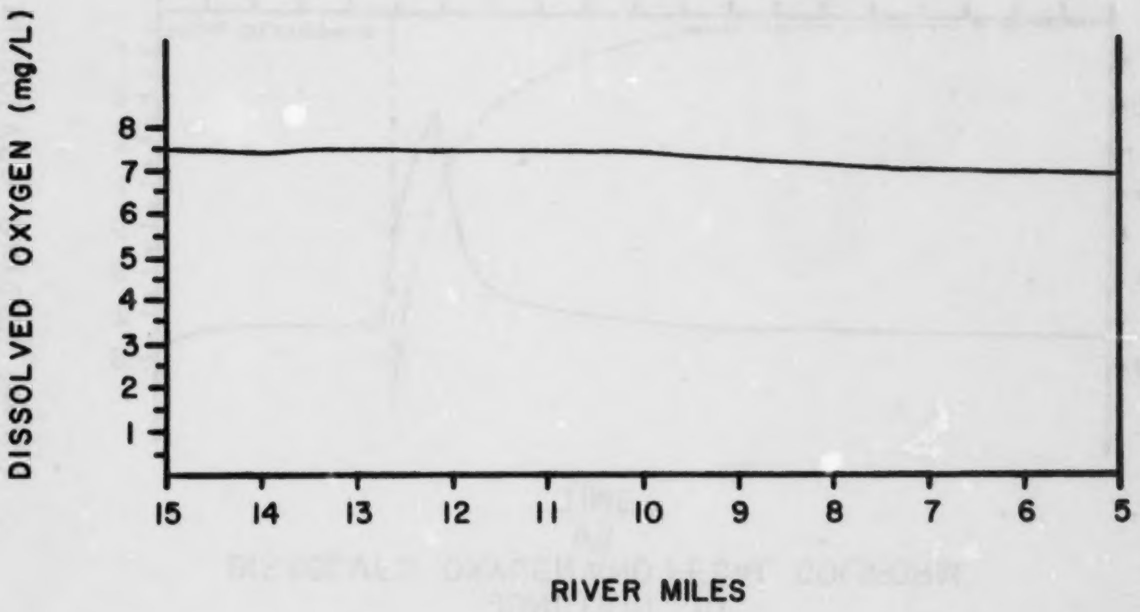


FIGURE IV-25
CLEAR CREEK - TIDAL
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT B

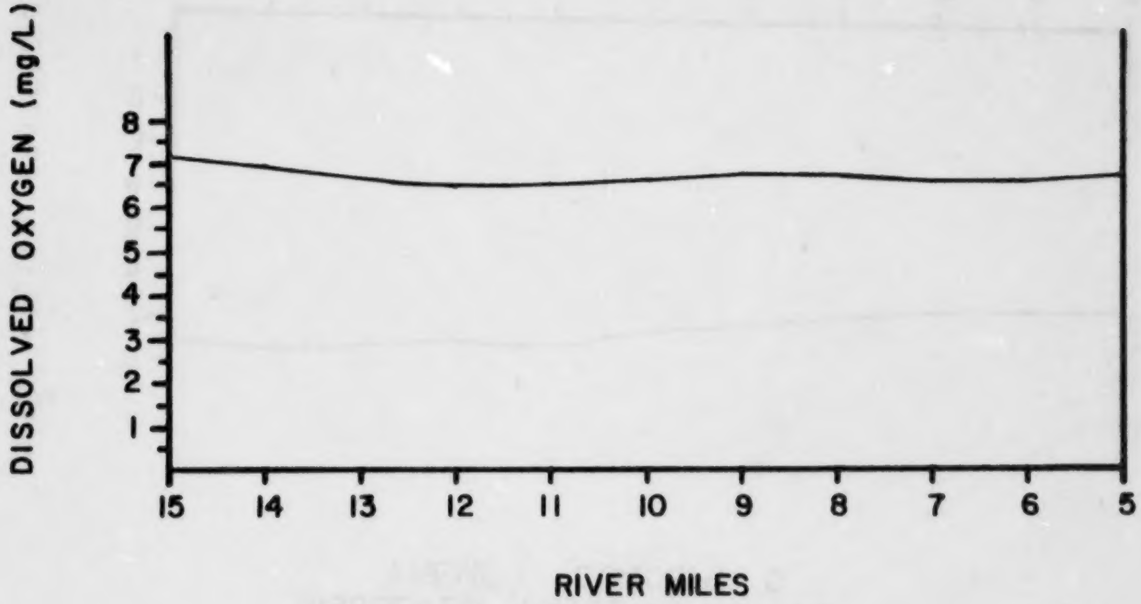


FIGURE IV-26
CLEAR CREEK- TIDAL
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT C

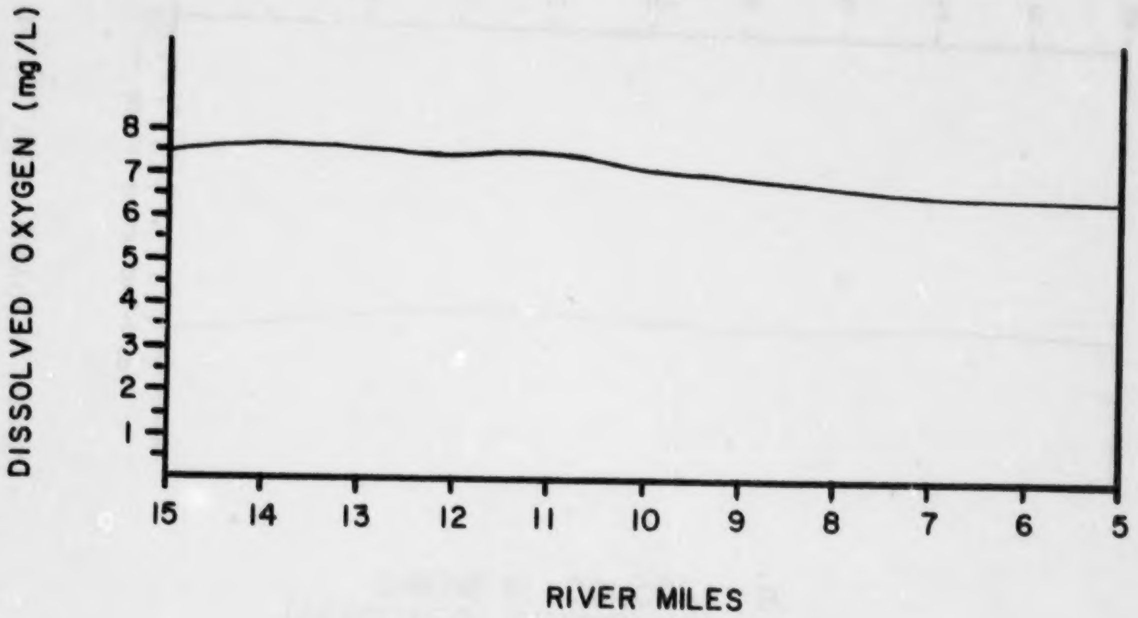


FIGURE IV-27
CLEAR LAKE
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT A

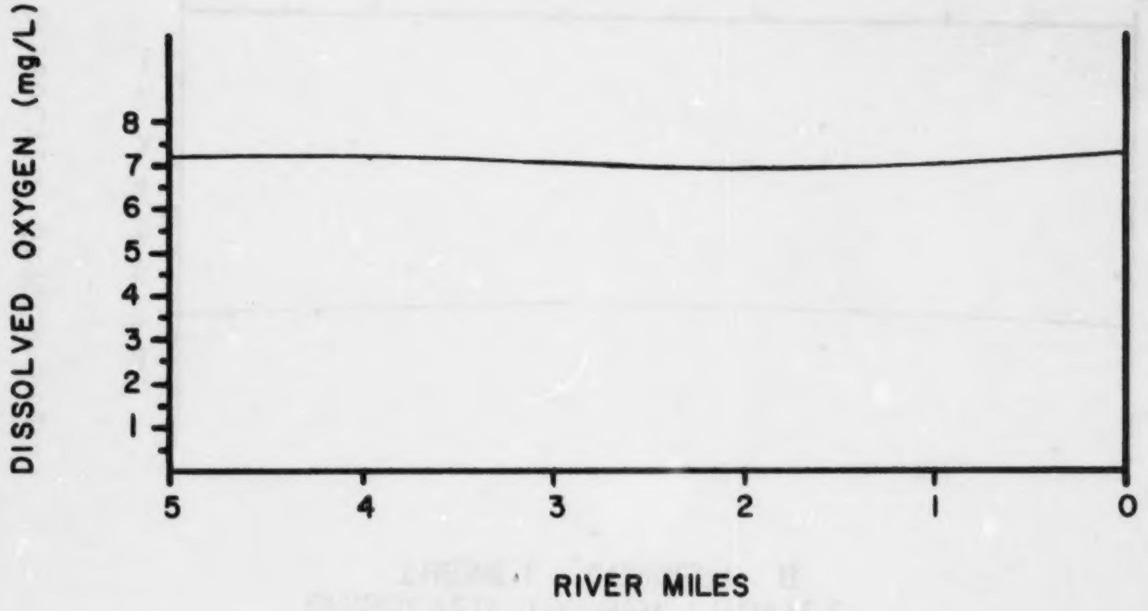


FIGURE IV-28
CLEAR LAKE
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT B

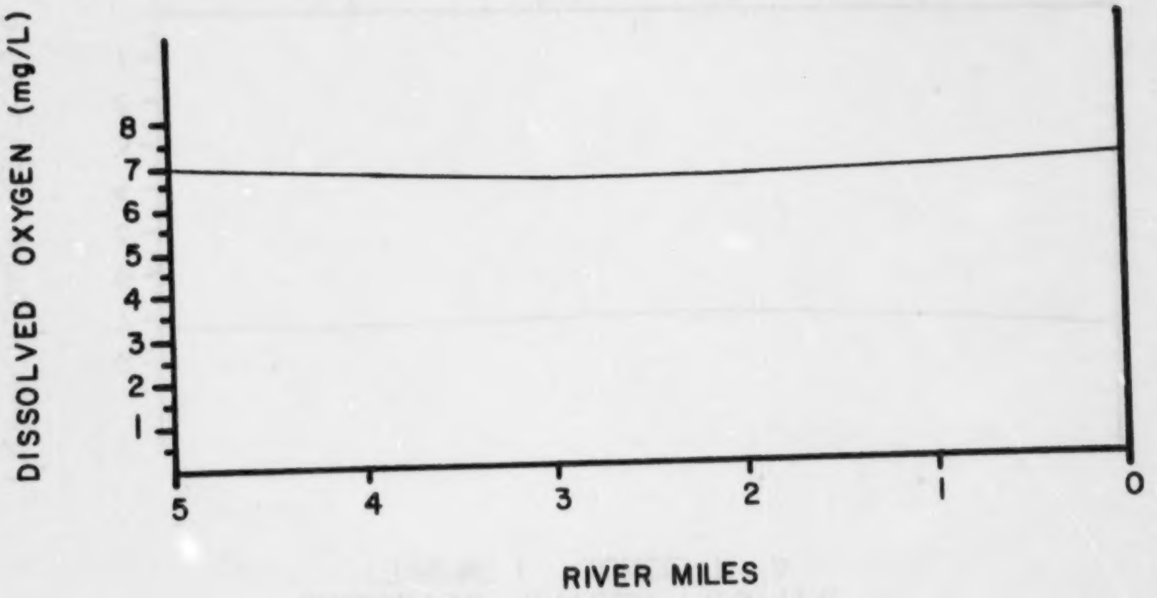


FIGURE IV-29
CLEAR LAKE
DISSOLVED OXYGEN PROFILE
THEME I CONCEPT C

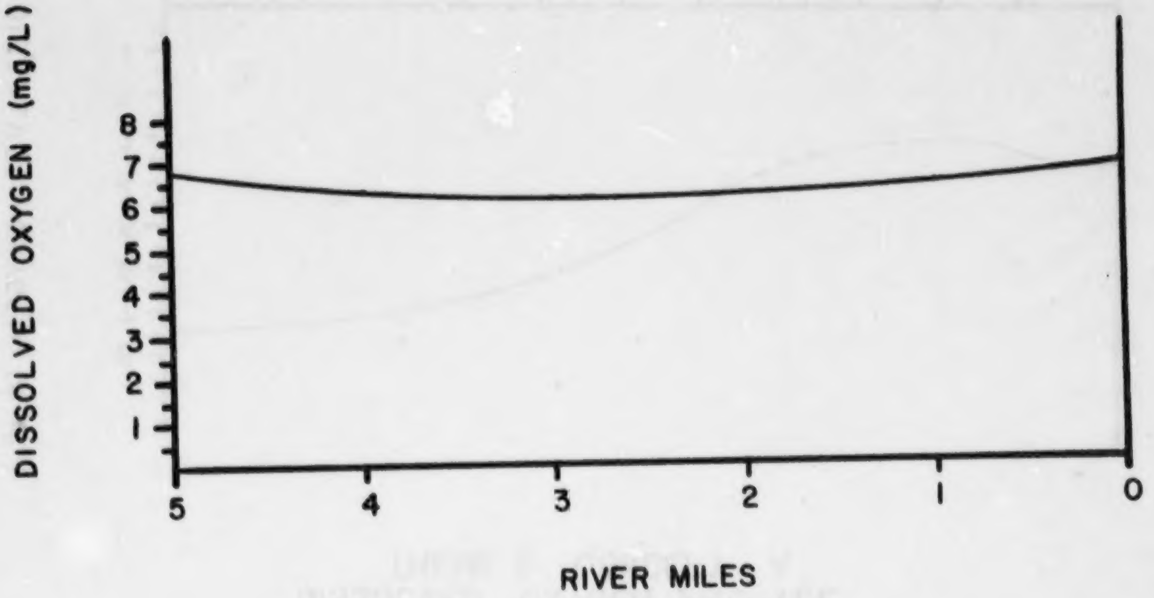


FIGURE IV - 30
ARMAND BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

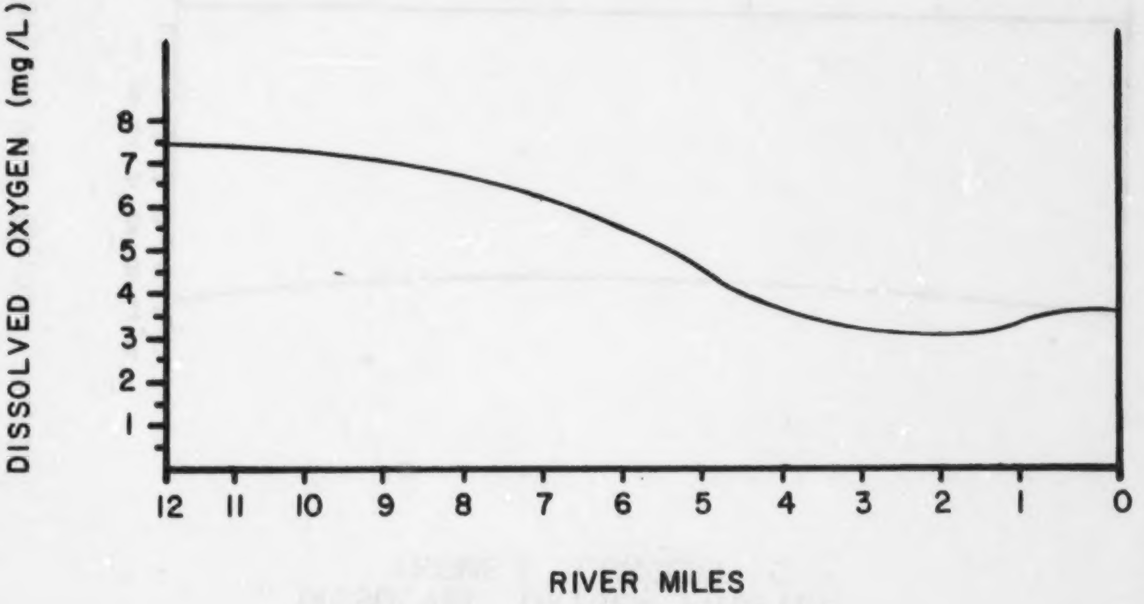


FIGURE IV- 31
ARMAND BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

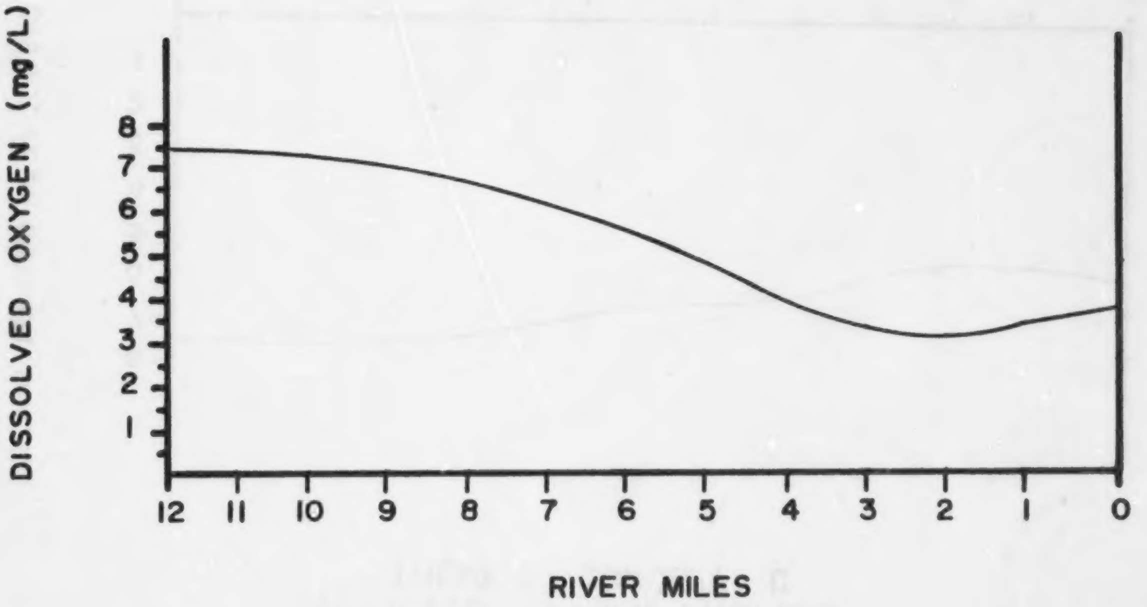


FIGURE IV- 32
ARMAND BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

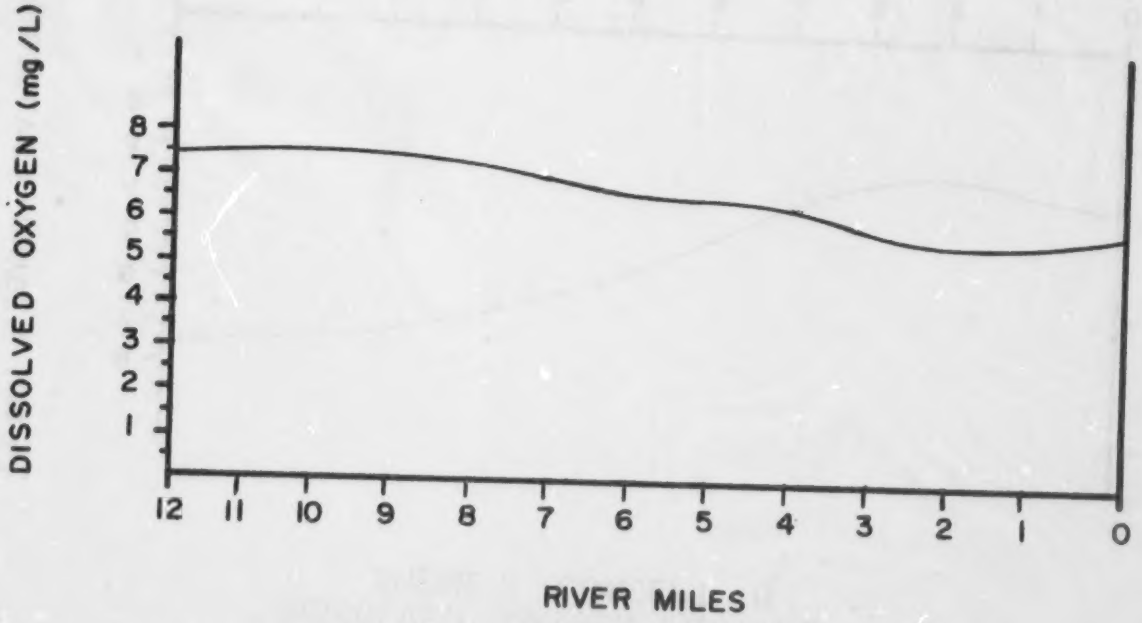
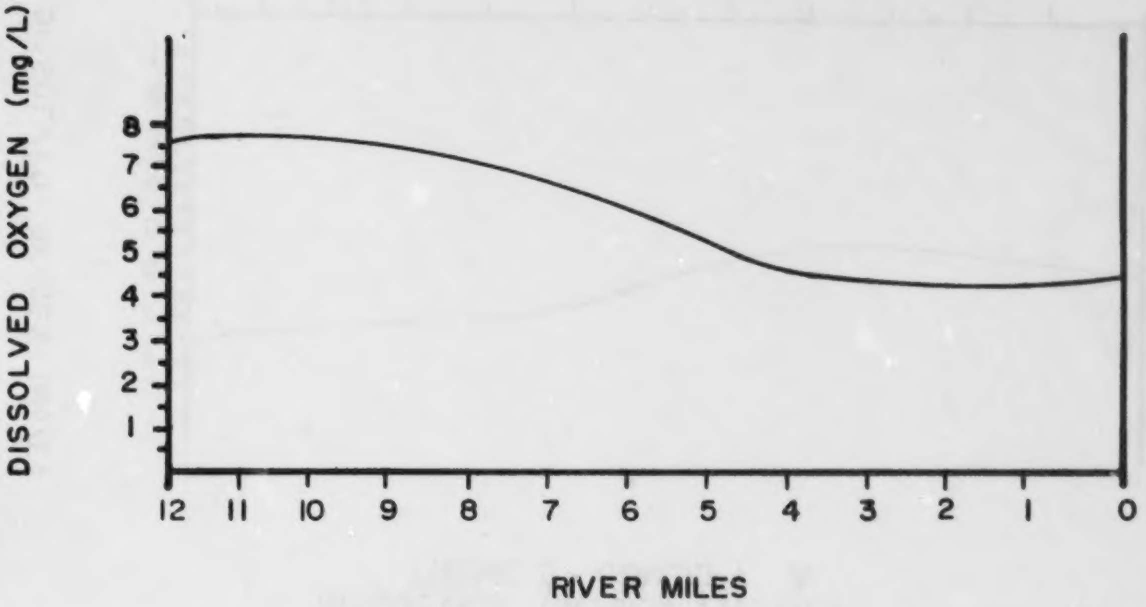


FIGURE IV-33
ARMAND BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A



RIVER MILES

FIGURE IV-34
ARMAND BAYOU
DISSOLVED OXYGEN PROFILE
THEME 5 CONCEPT A

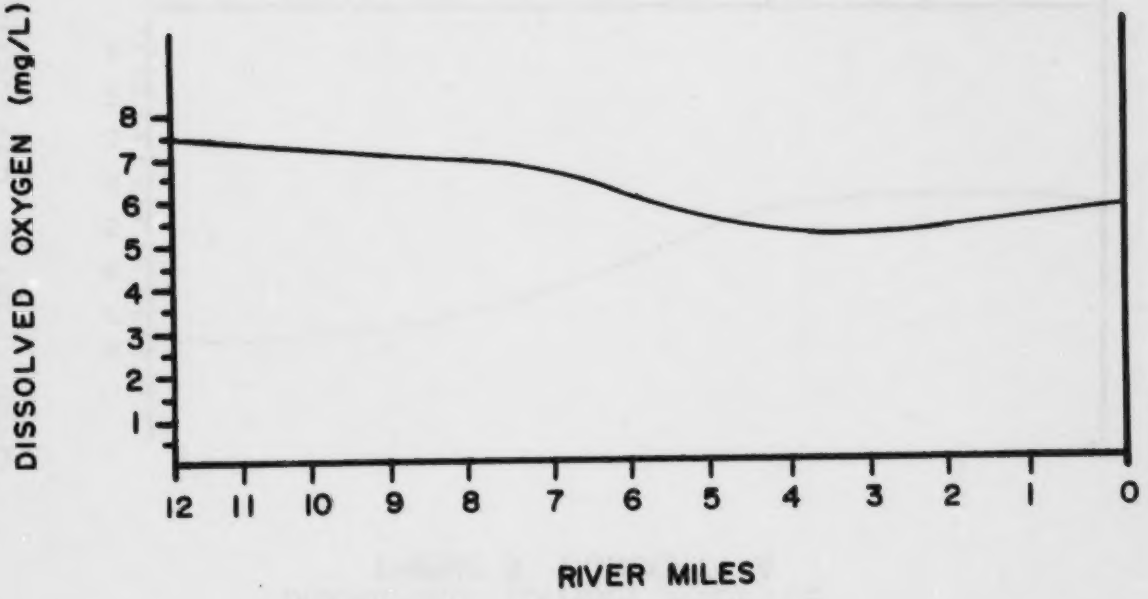


FIGURE IV- 35
DICKINSON BAYOU- TIDAL
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

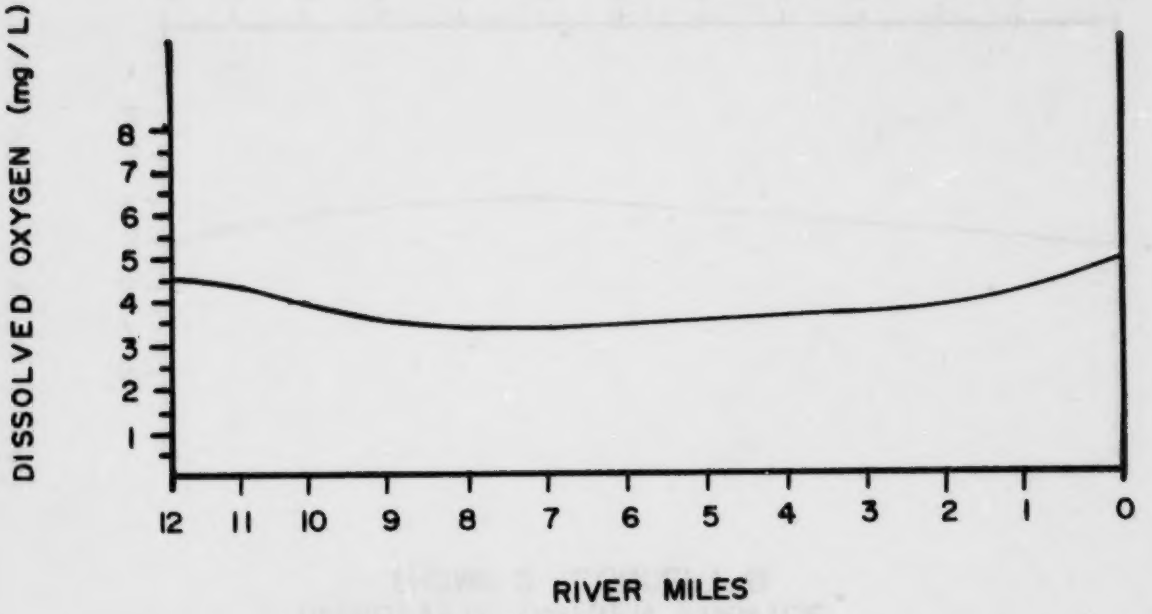


FIGURE IV - 36
DICKINSON BAYOU - TIDAL
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

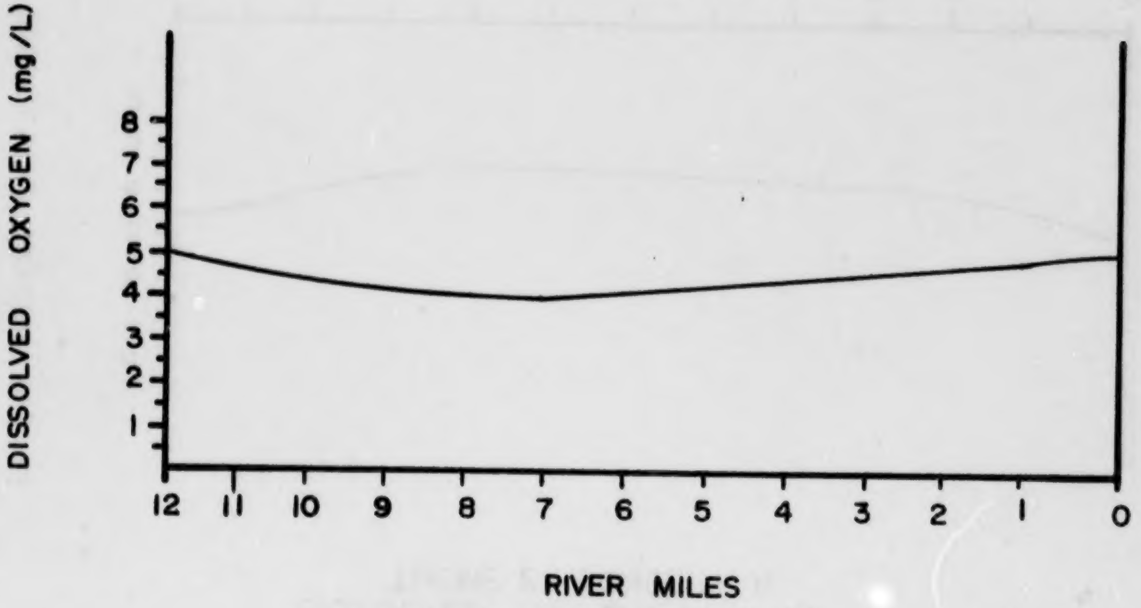


FIGURE IV-37
DICKINSON BAYOU-TIDAL
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

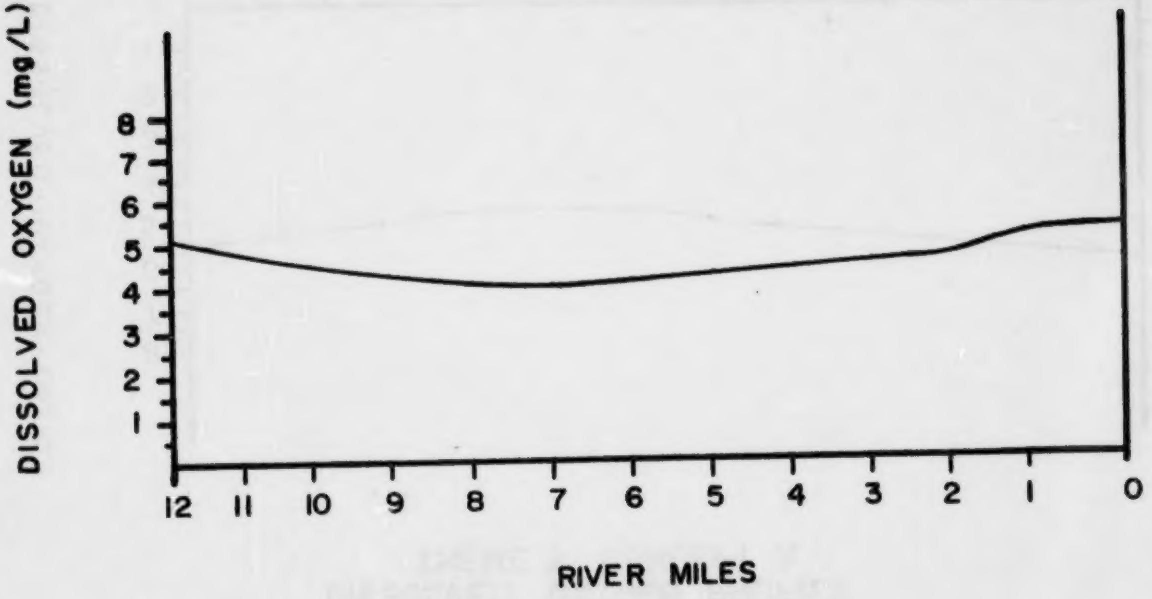


FIGURE IV-38
DICKINSON BAYOU- TIDAL
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

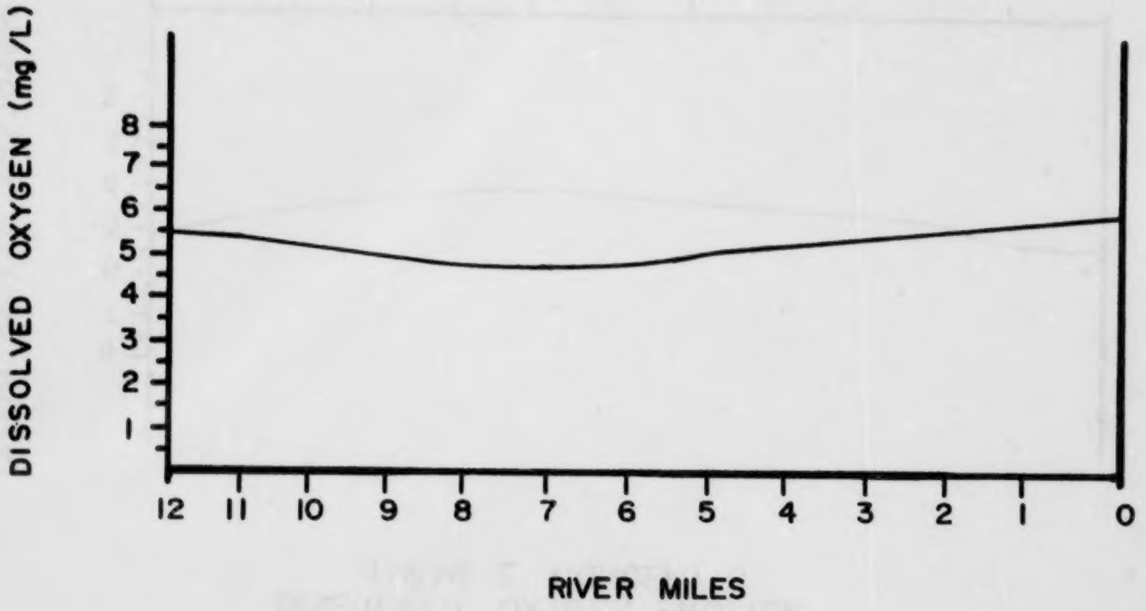


FIGURE IV - 39
DICKINSON BAYOU - TIDAL
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT B

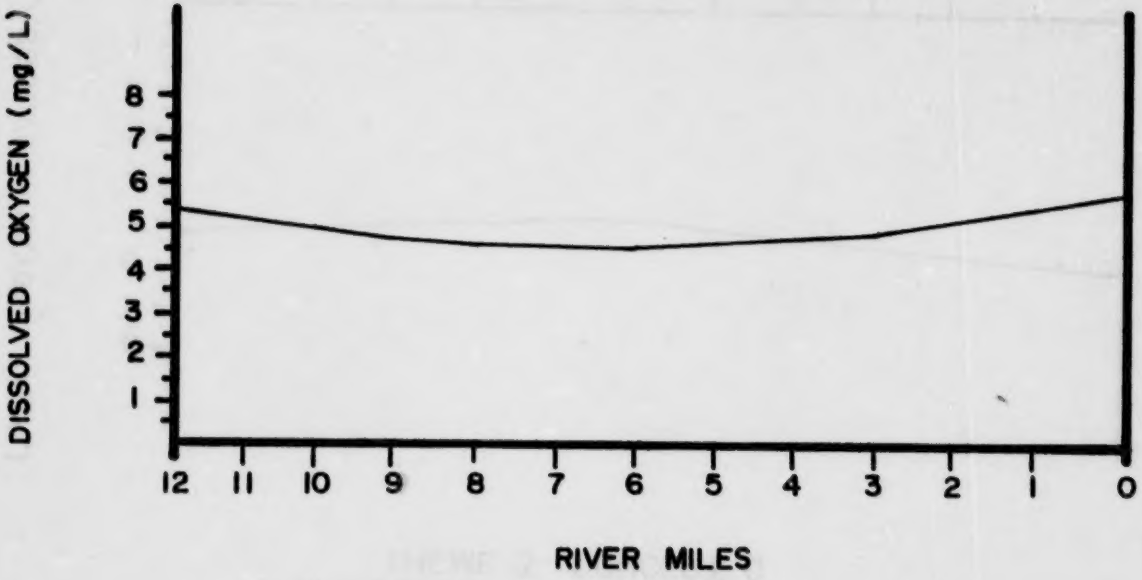


FIGURE IV-40
DICKINSON BAYOU-TIDAL
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT C

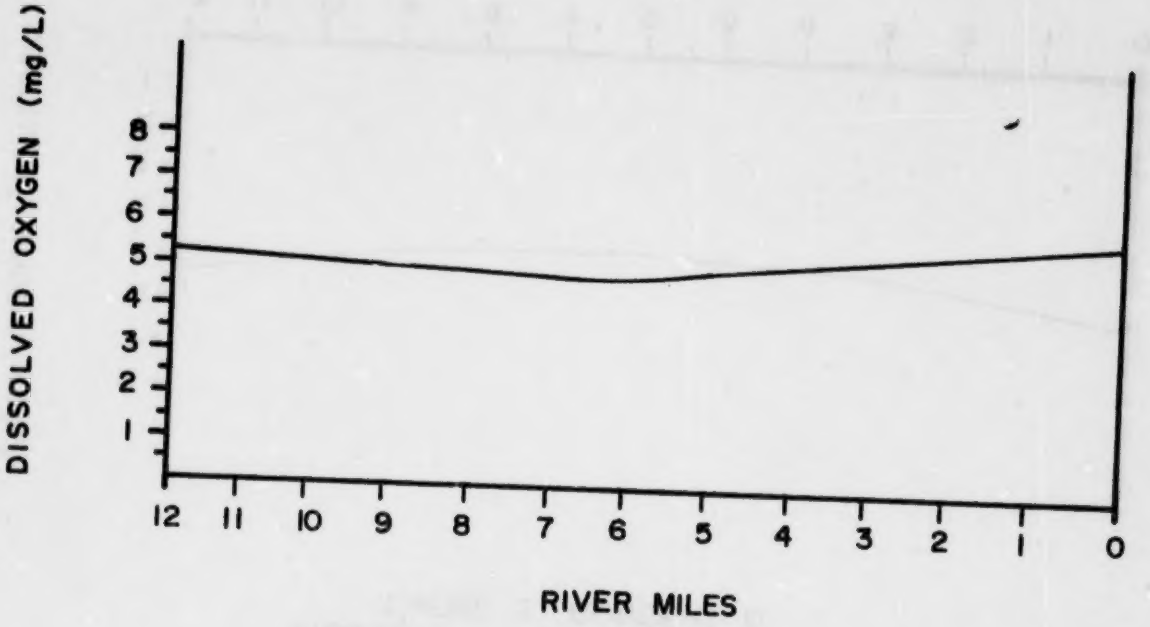


FIGURE V - I
HOUSTON SHIP CHANNEL
SEGMENT 1006 AND 1007
DISSOLVED OXYGEN VS. RIVER MILE
THEME I CONCEPT A

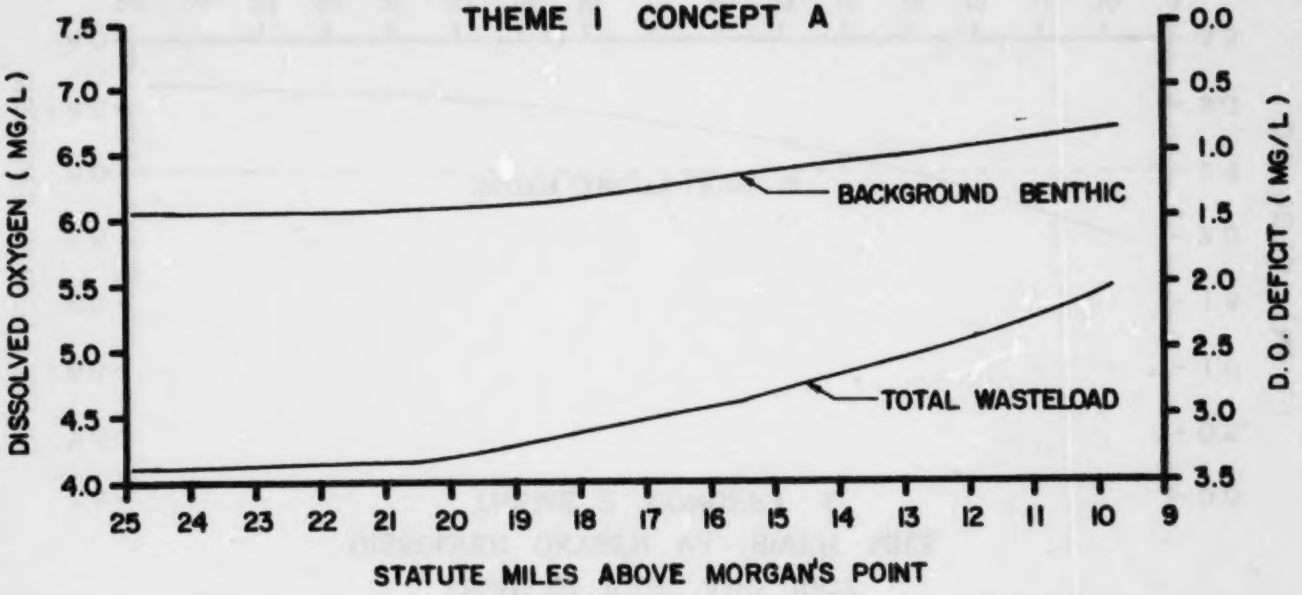


FIGURE V - 2
HOUSTON SHIP CHANNEL
SEGMENT 1006 AND 1007
DISSOLVED OXYGEN VS. RIVER MILE
THEME 2 CONCEPT A

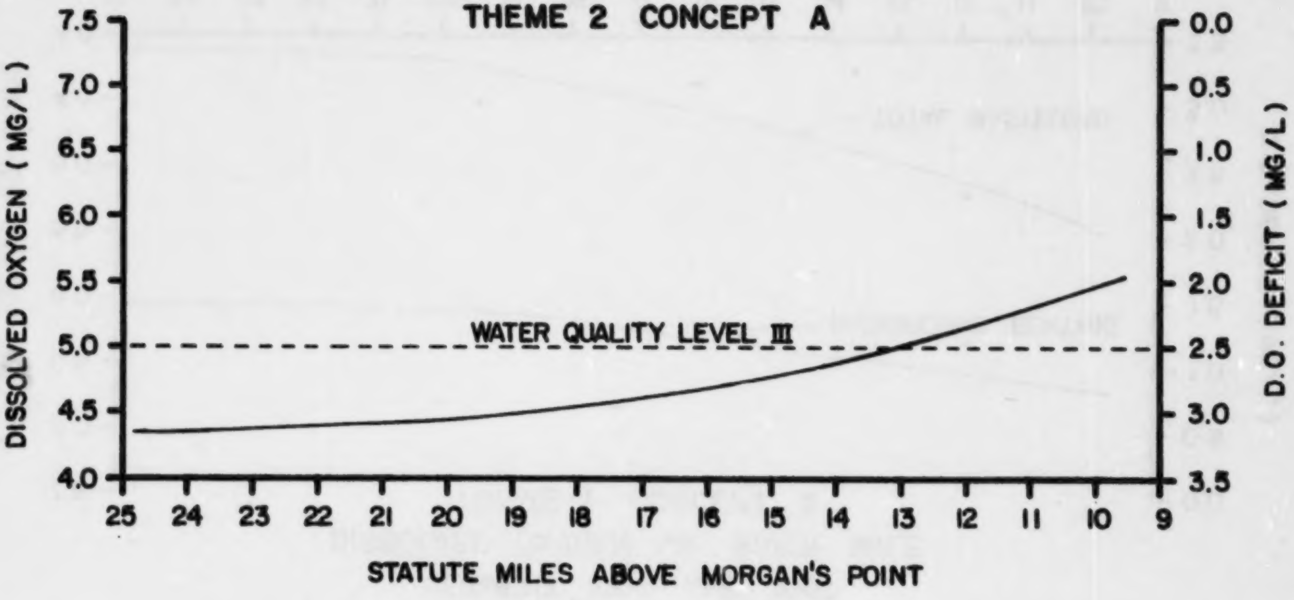


FIGURE V - 3
HOUSTON SHIP CHANNEL
SEGMENT 1006 AND 1007
DISSOLVED OXYGEN VS. RIVER MILE
THEME 3 CONCEPT A

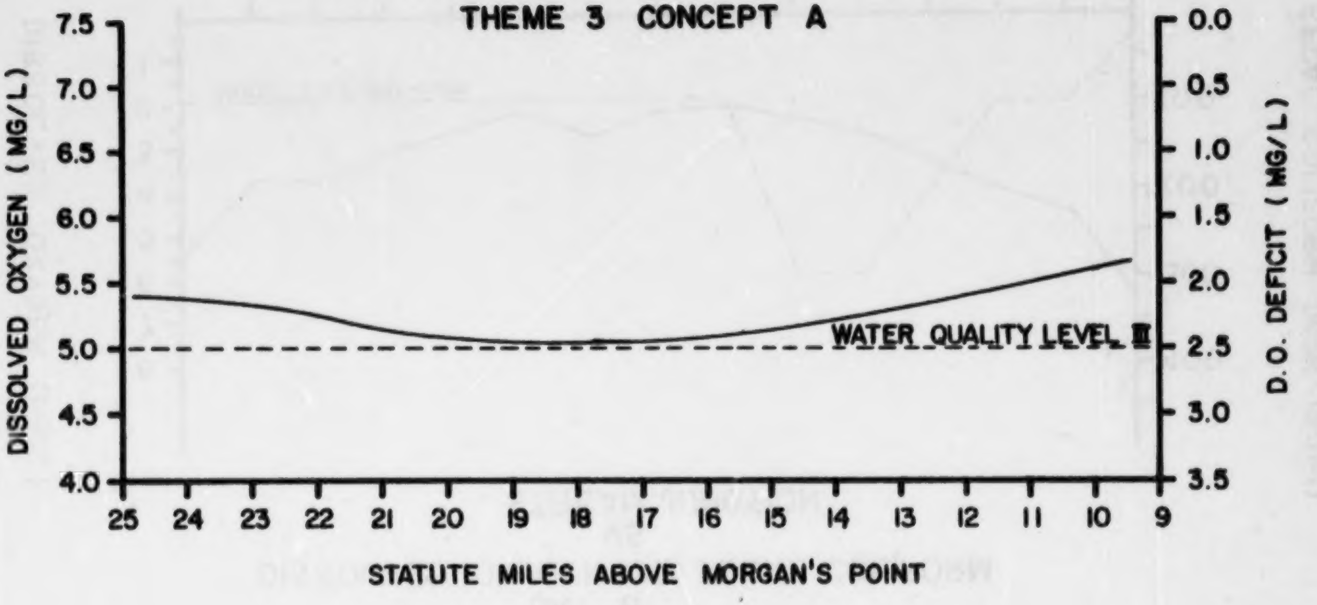


FIGURE V-4
HOUSTON SHIP CHANNEL
DAY 8
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

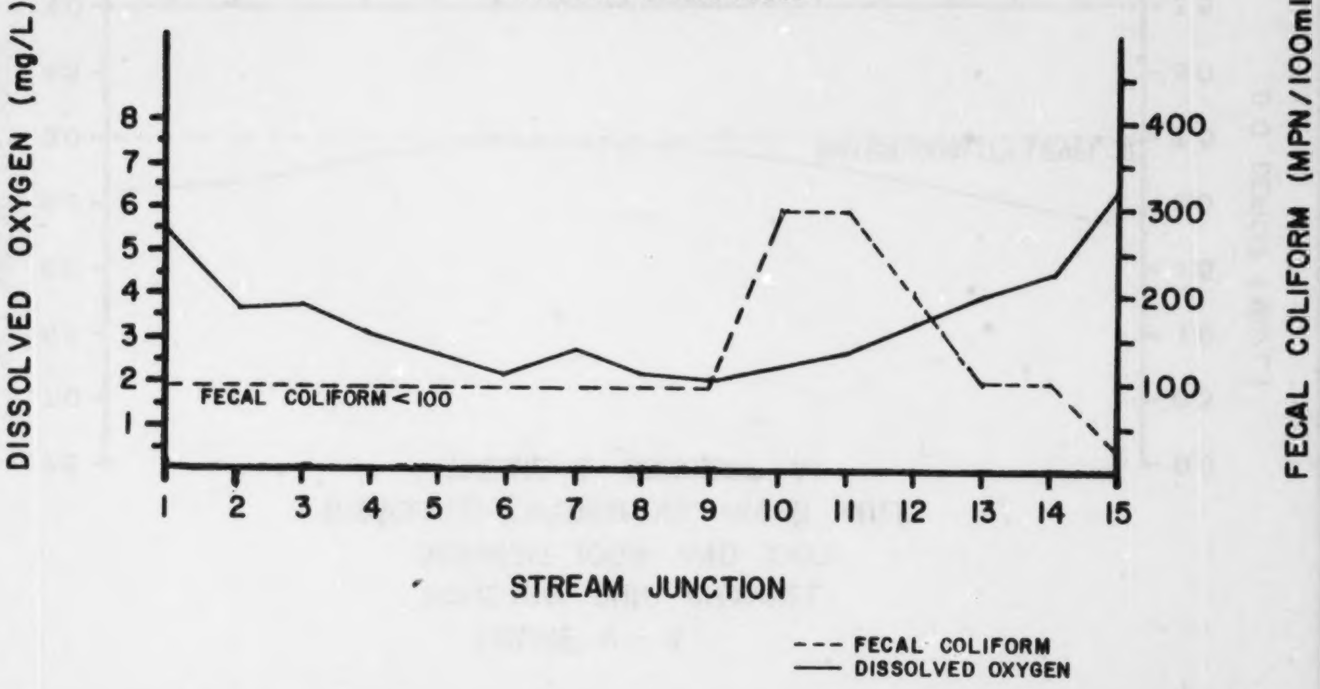


FIGURE V-5
HOUSTON SHIP CHANNEL
DAY 9
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

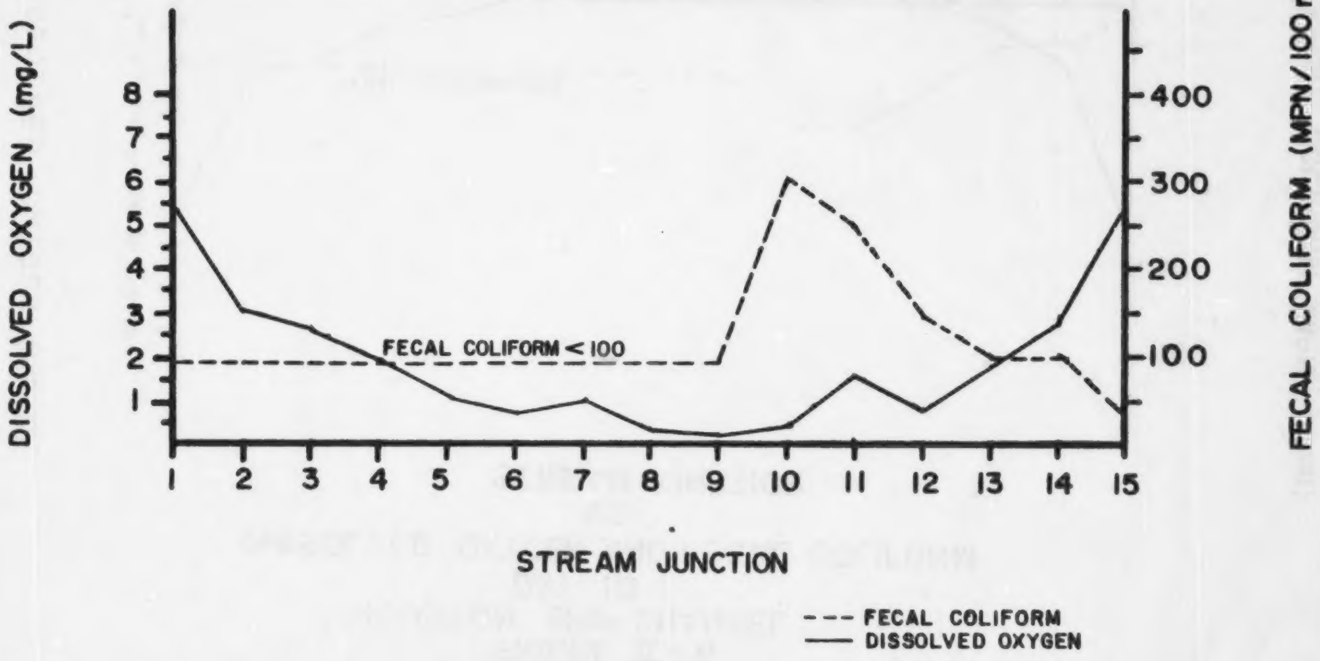


FIGURE V-6
HOUSTON SHIP CHANNEL
DAY 10
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

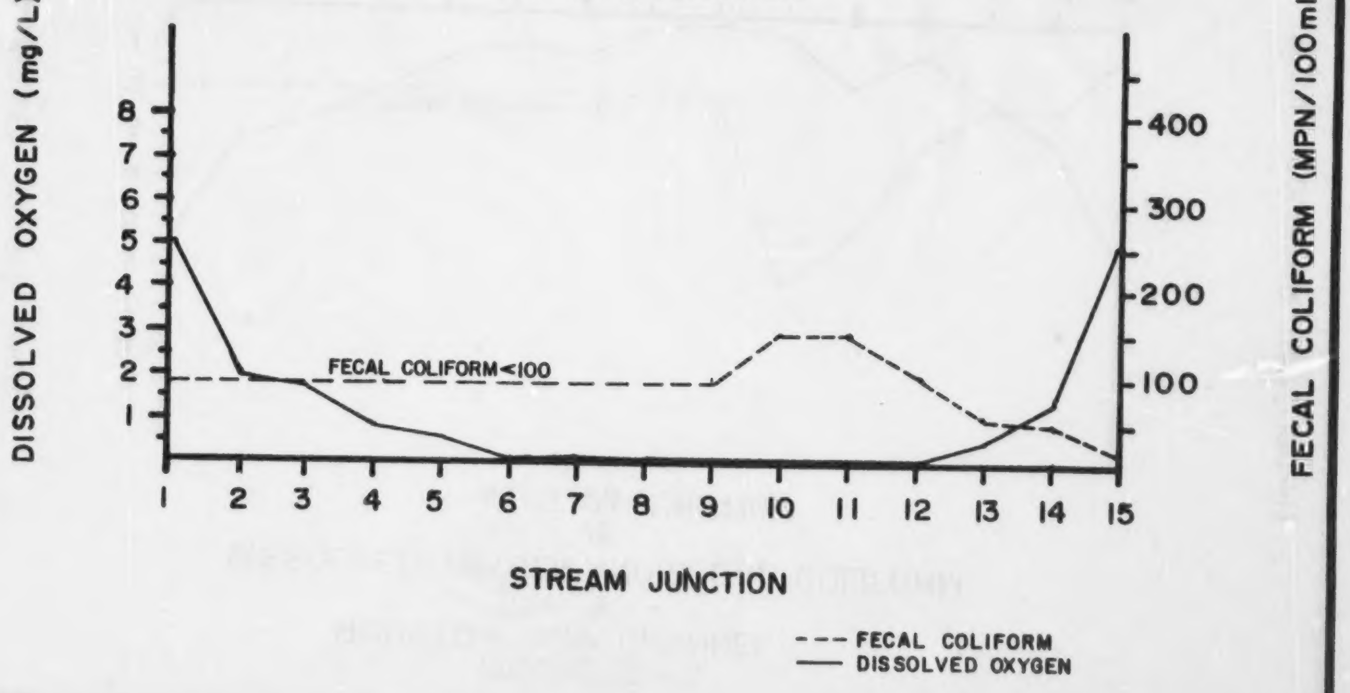


FIGURE Ⅵ-7
HOUSTON SHIP CHANNEL
DAY 12
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

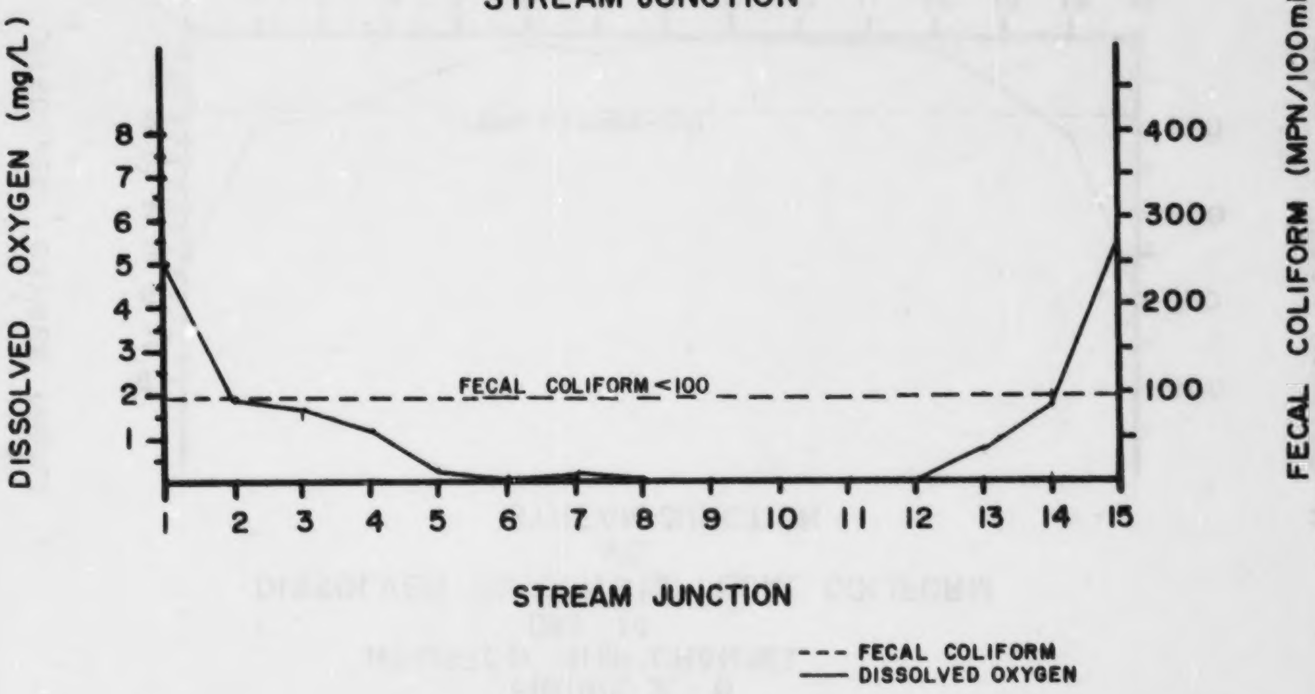


FIGURE V - 8
HOUSTON SHIP CHANNEL
DAY 14
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

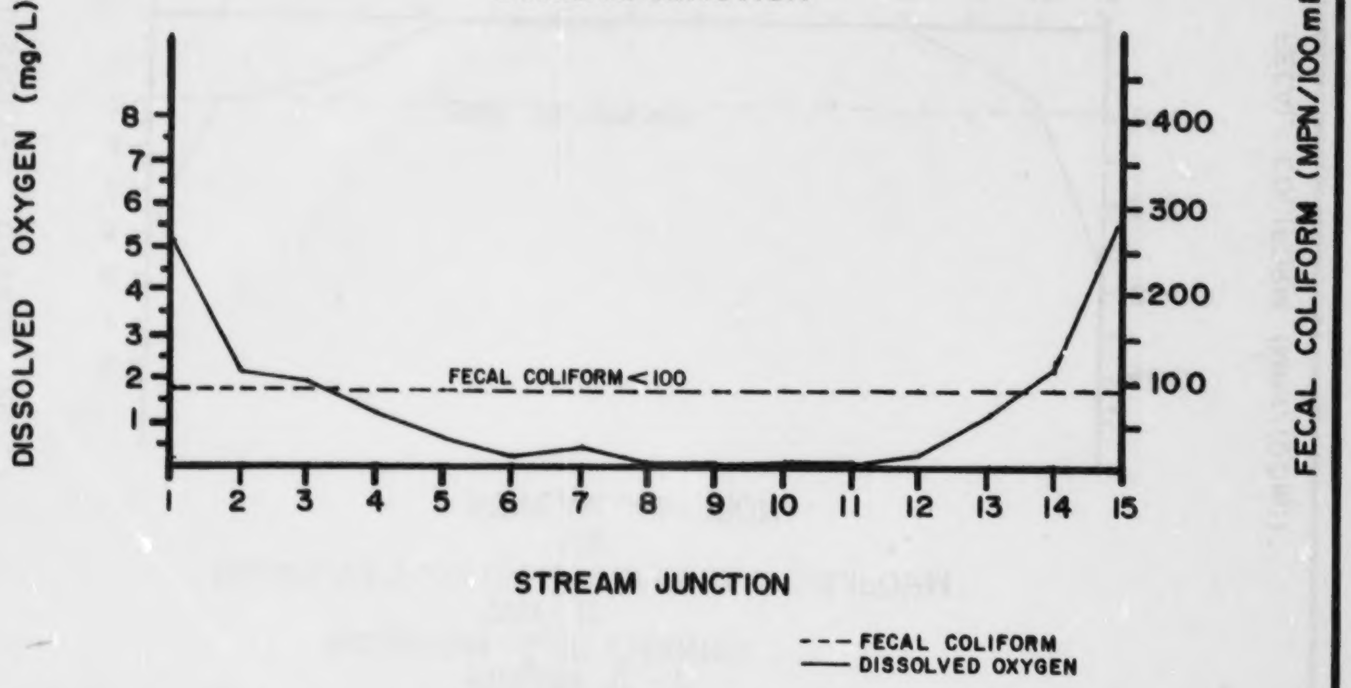


FIGURE V-9
HOUSTON SHIP CHANNEL
DAY 16
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

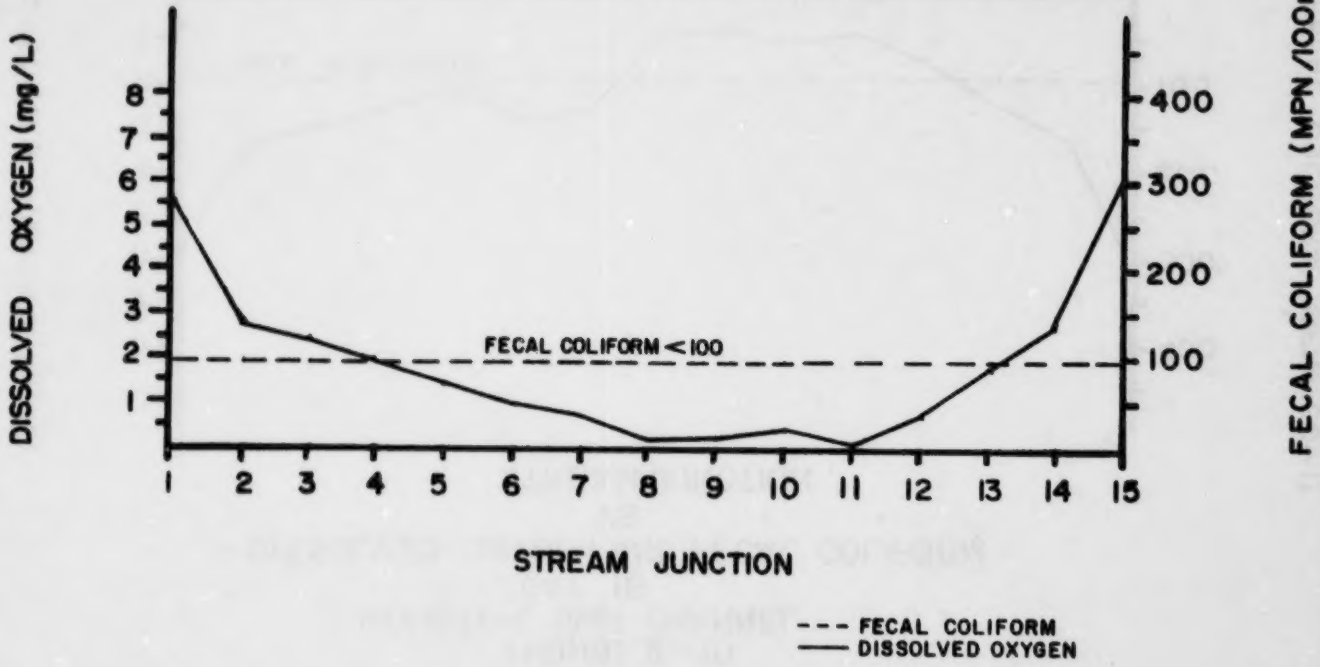


FIGURE V-10
HOUSTON SHIP CHANNEL
DAY 18
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

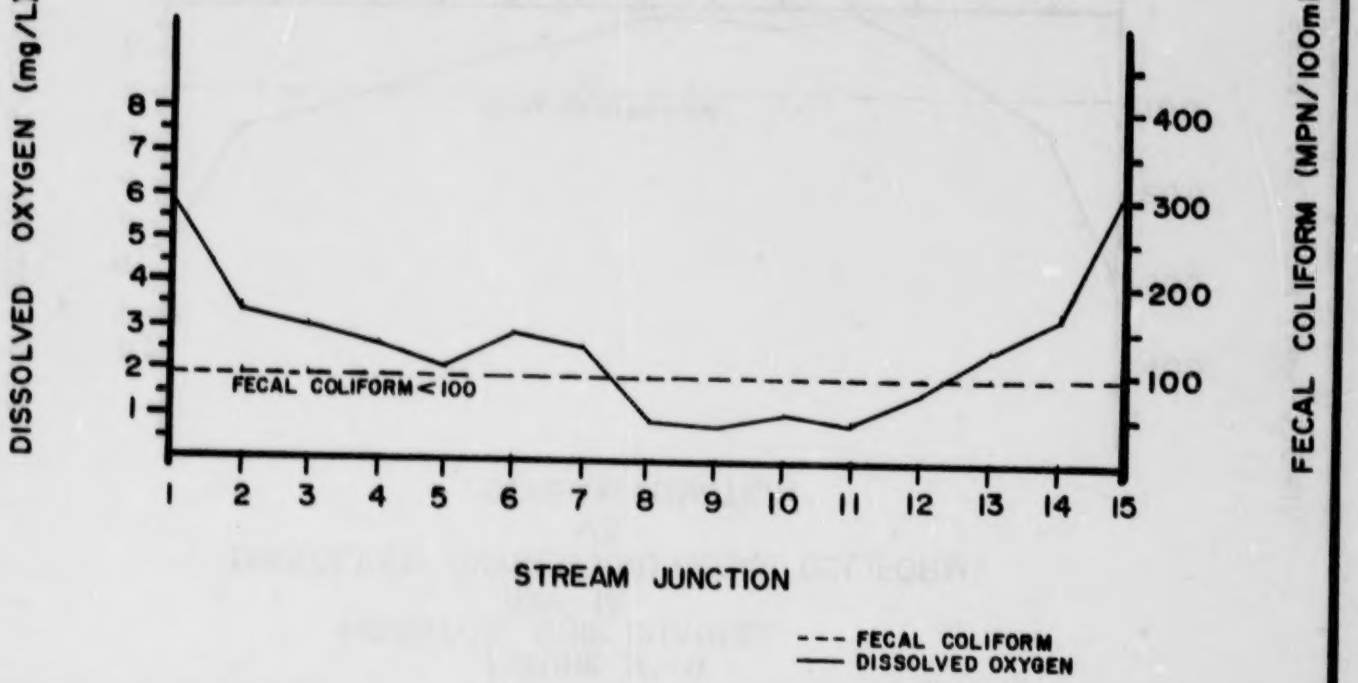


FIGURE V-11
HOUSTON SHIP CHANNEL
DAY 20
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

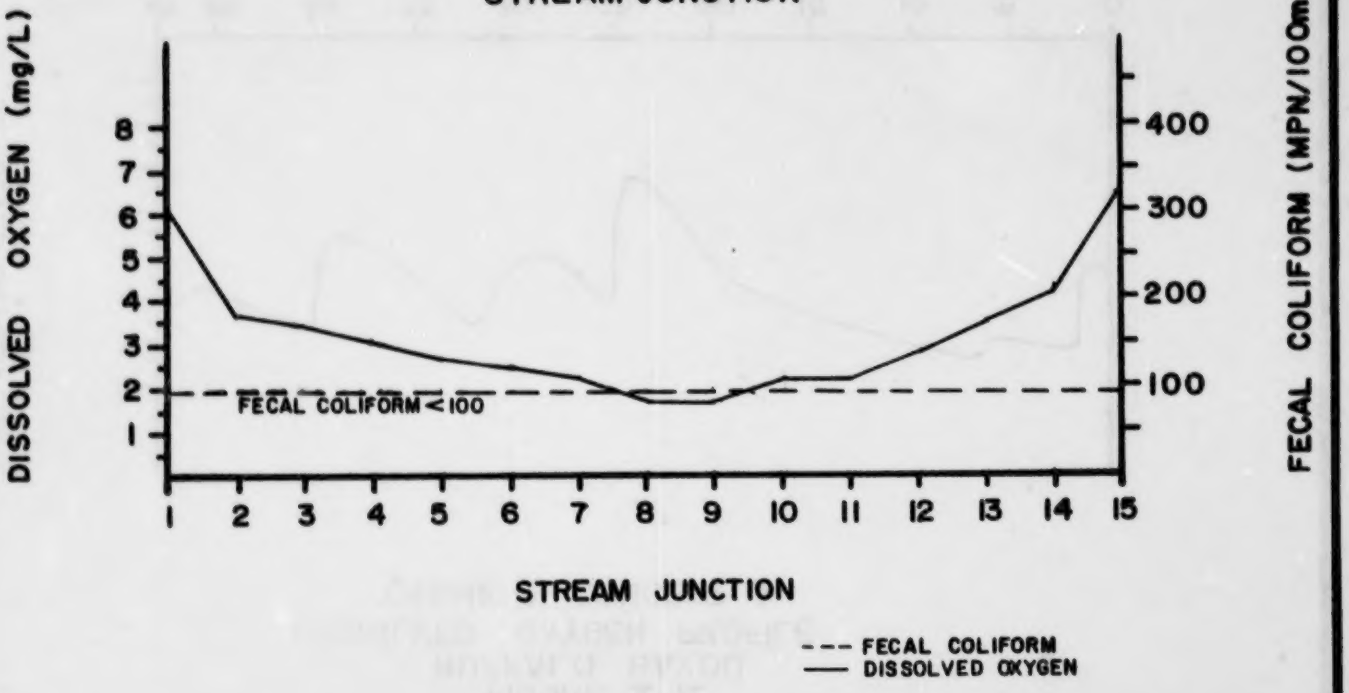


FIGURE V-12
BUFFALO BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

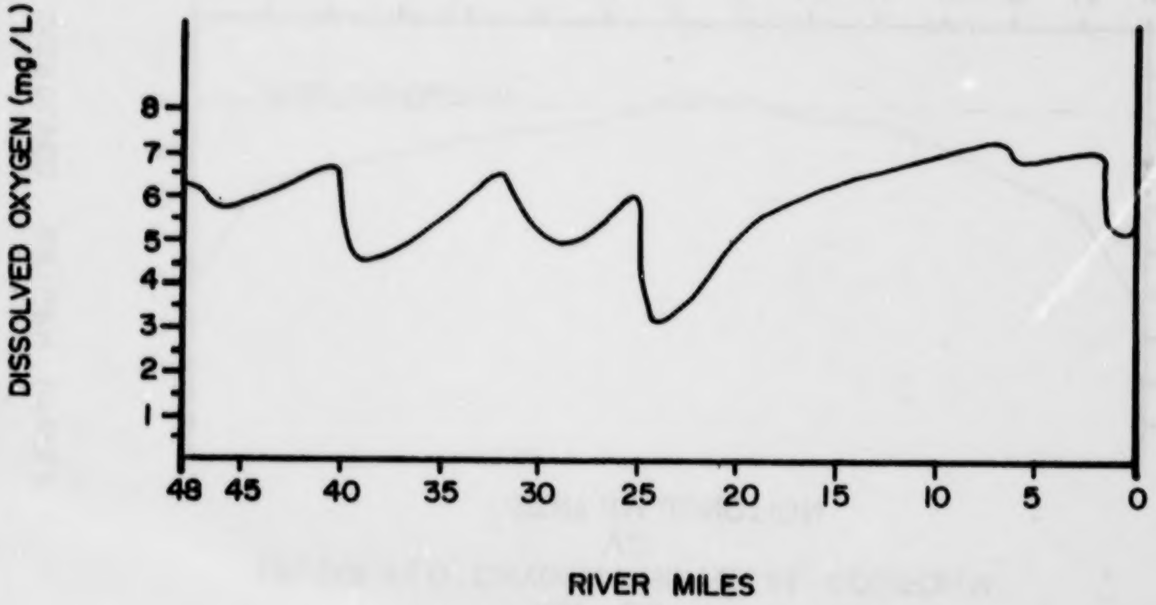


FIGURE V-13
BUFFALO BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

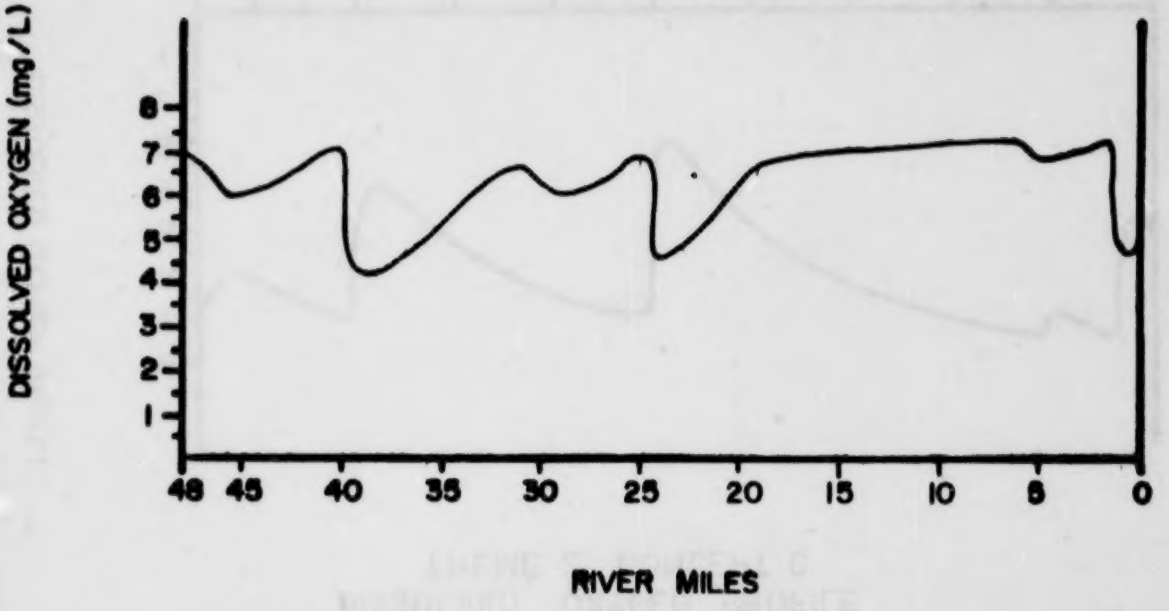


FIGURE Ⅴ-14
BUFFALO BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

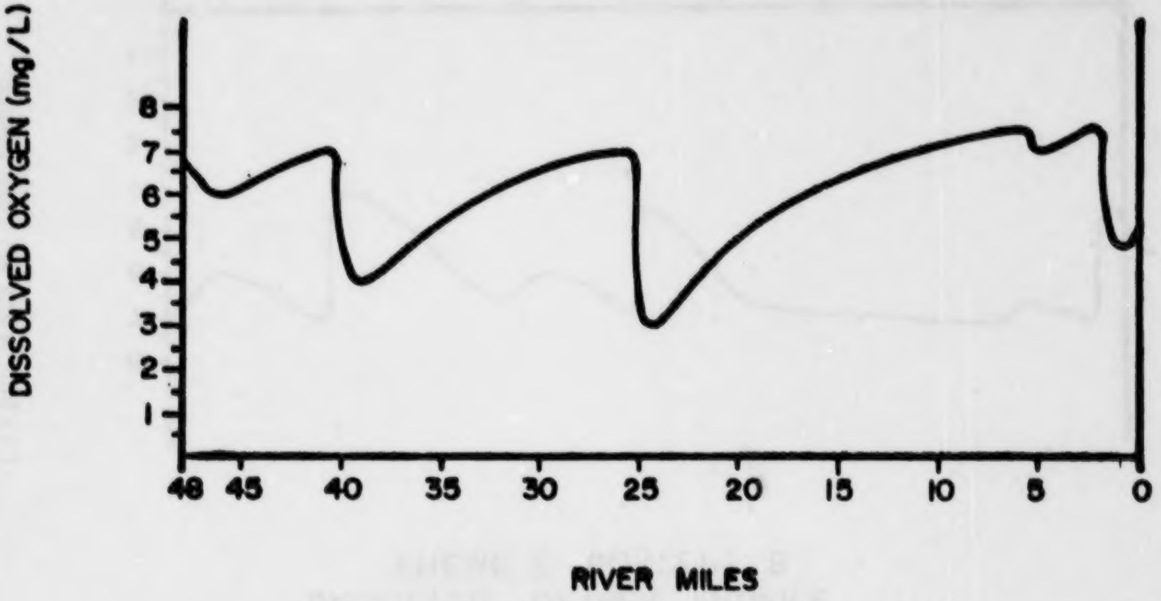
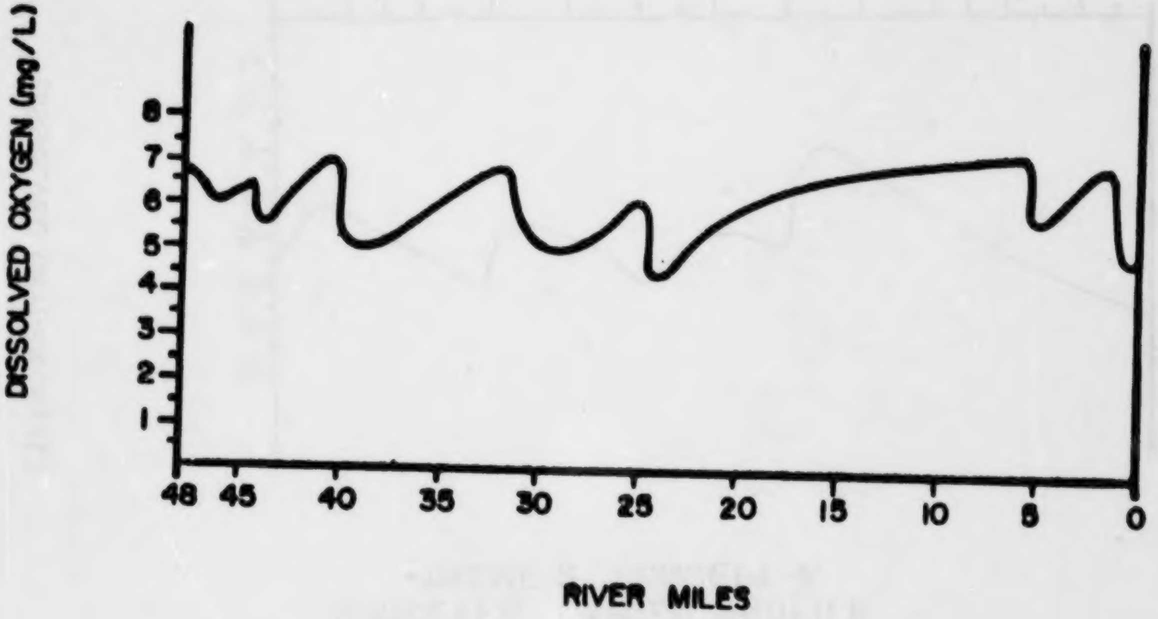


FIGURE V-15
BUFFALO BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A



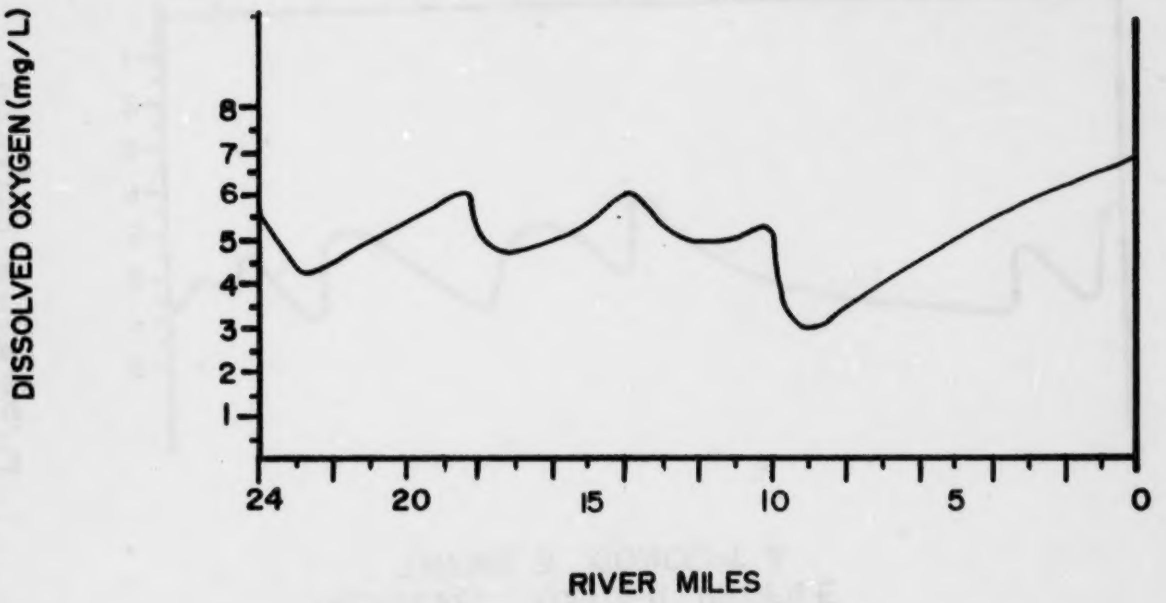


FIGURE V-16
WHITE OAK BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

FIGURE V-17
WHITE OAK BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

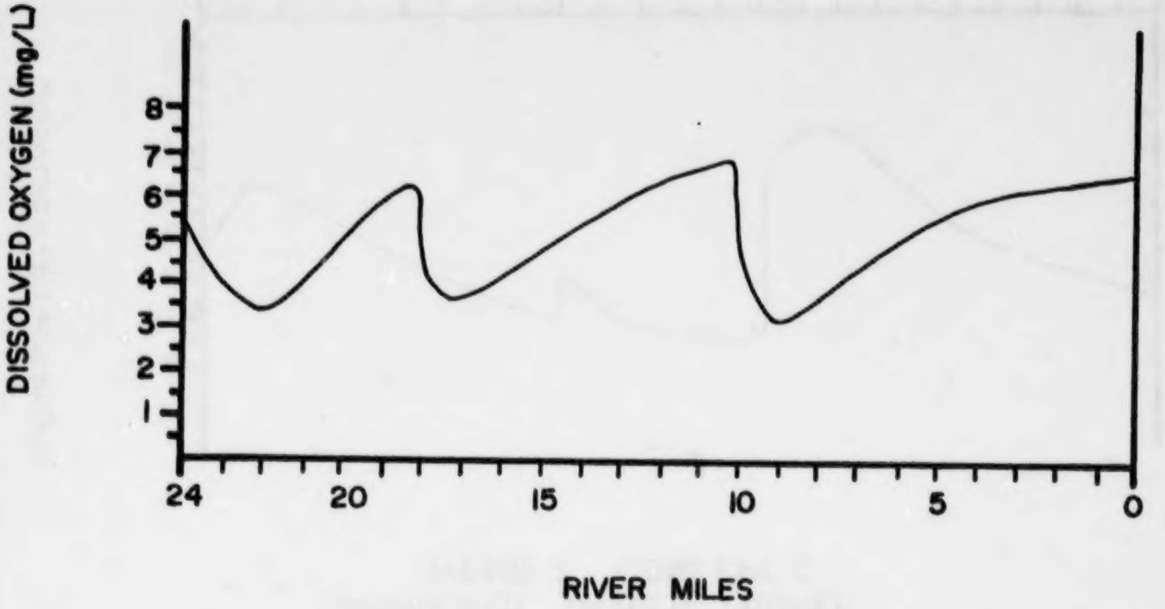


FIGURE V-18
WHITE OAK BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

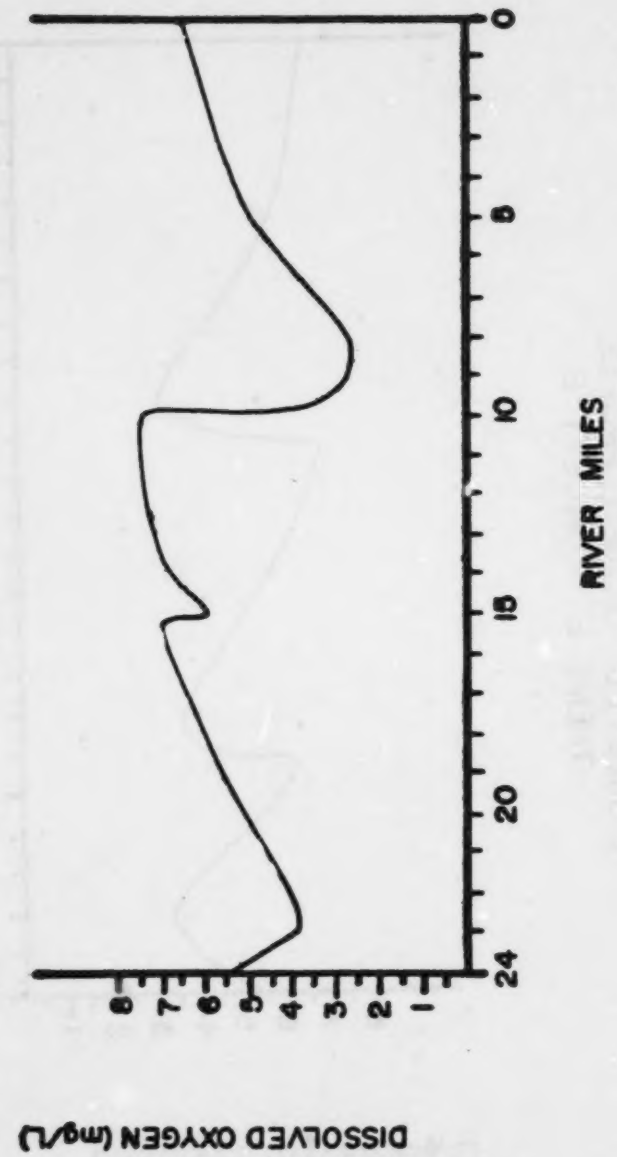


FIGURE V-19
WHITE OAK BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

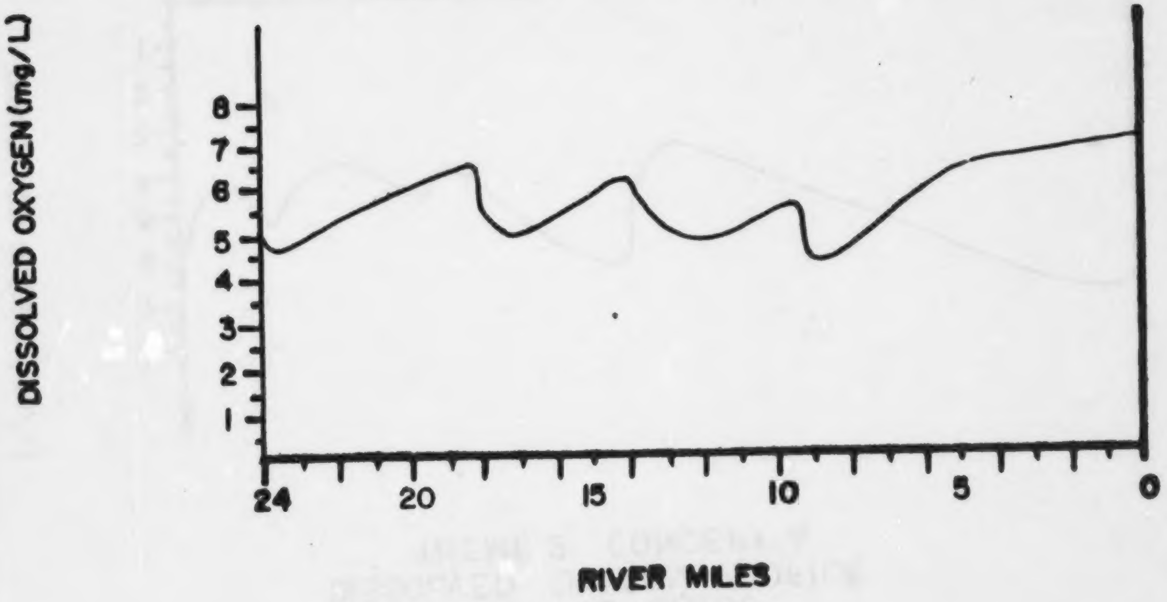


FIGURE Ⅴ-20
BRAYS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

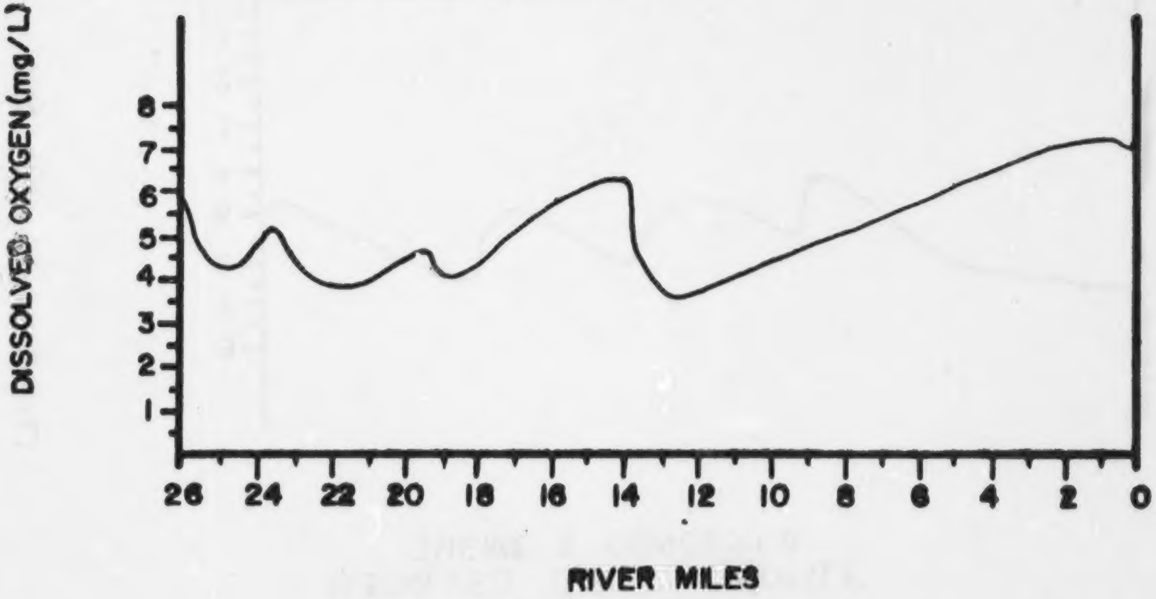


FIGURE V - 21
BRAYS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

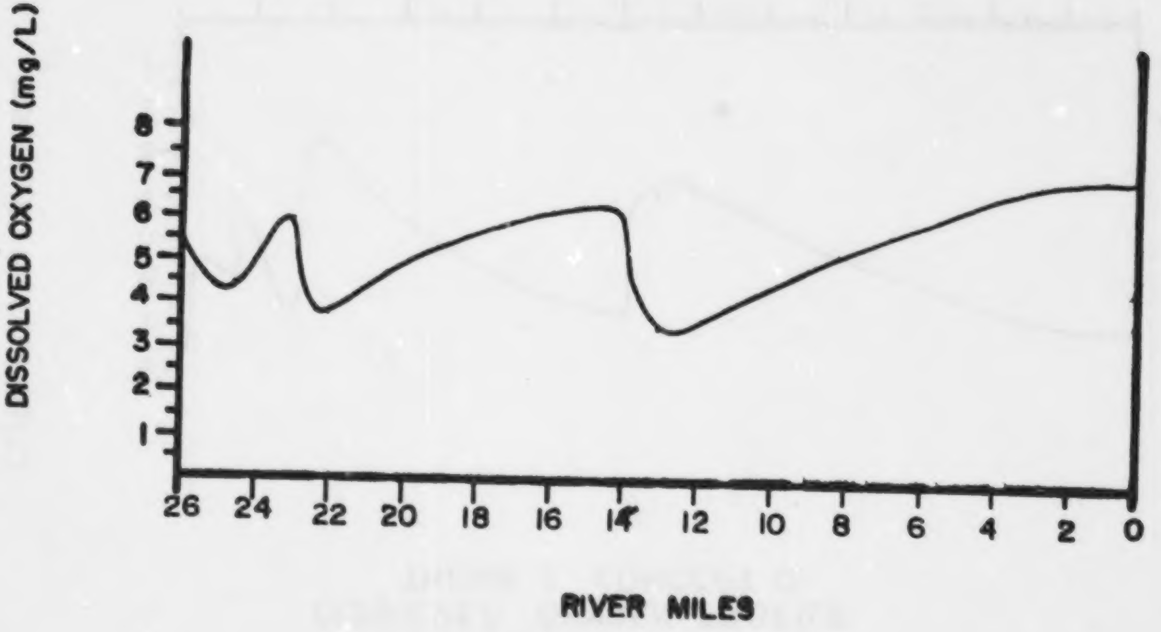


FIGURE V-22
BRAYS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

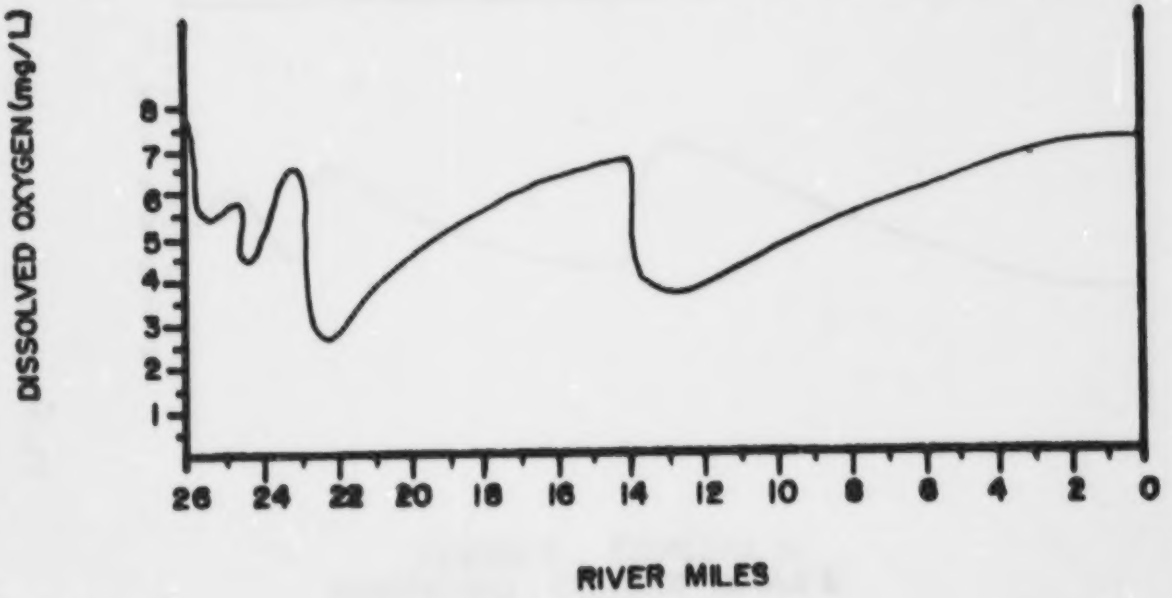


FIGURE V-23
BRAYS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

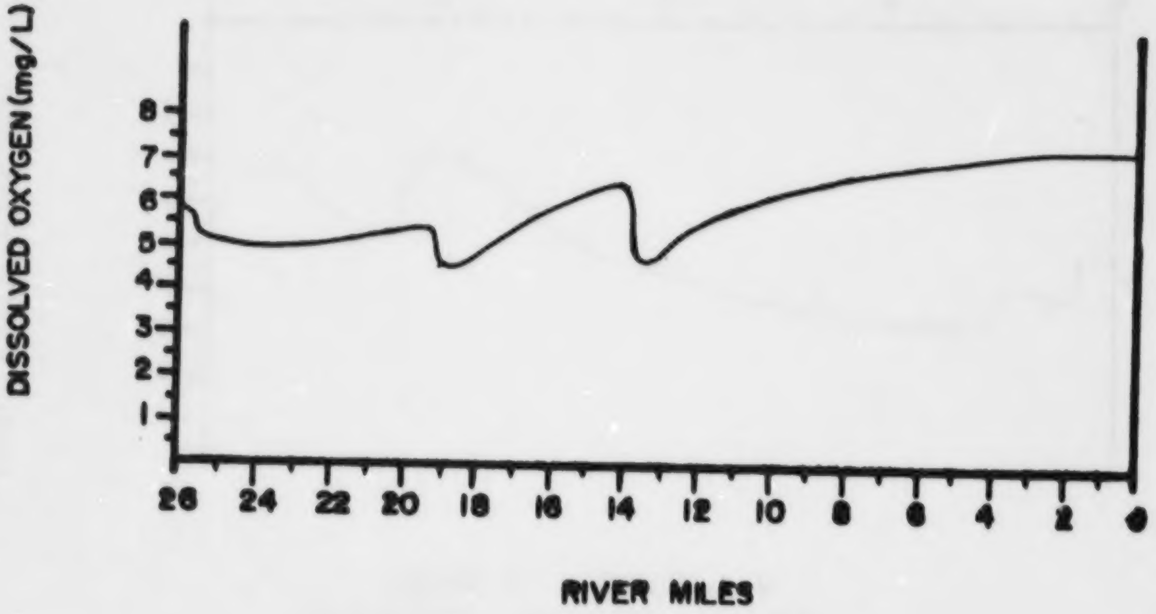


FIGURE V-24
SIMS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

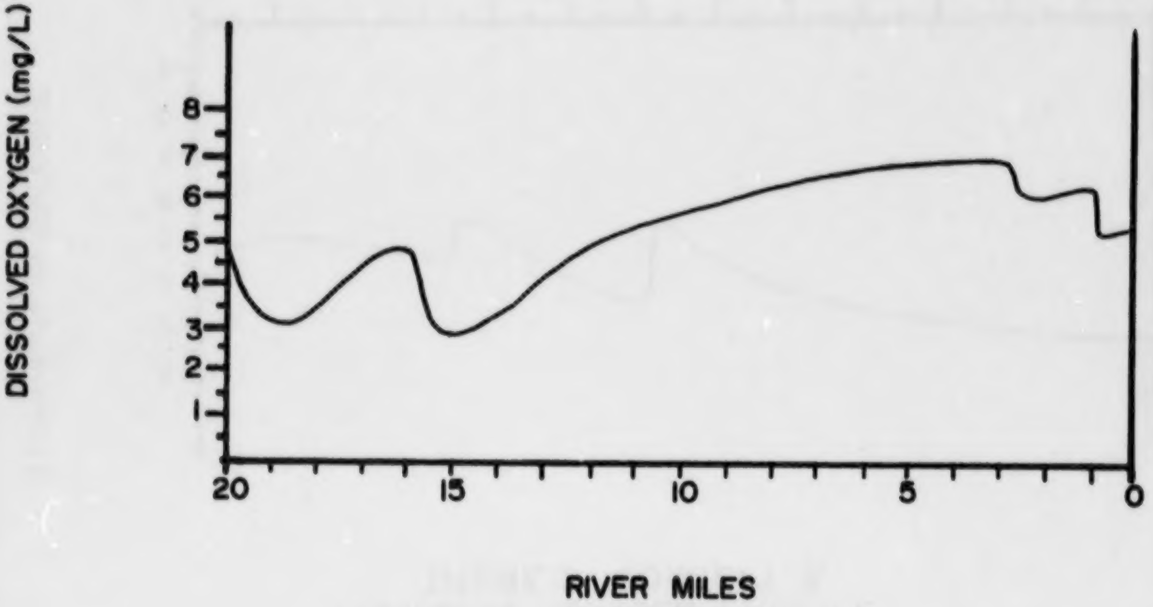


FIGURE V-25
SIMS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

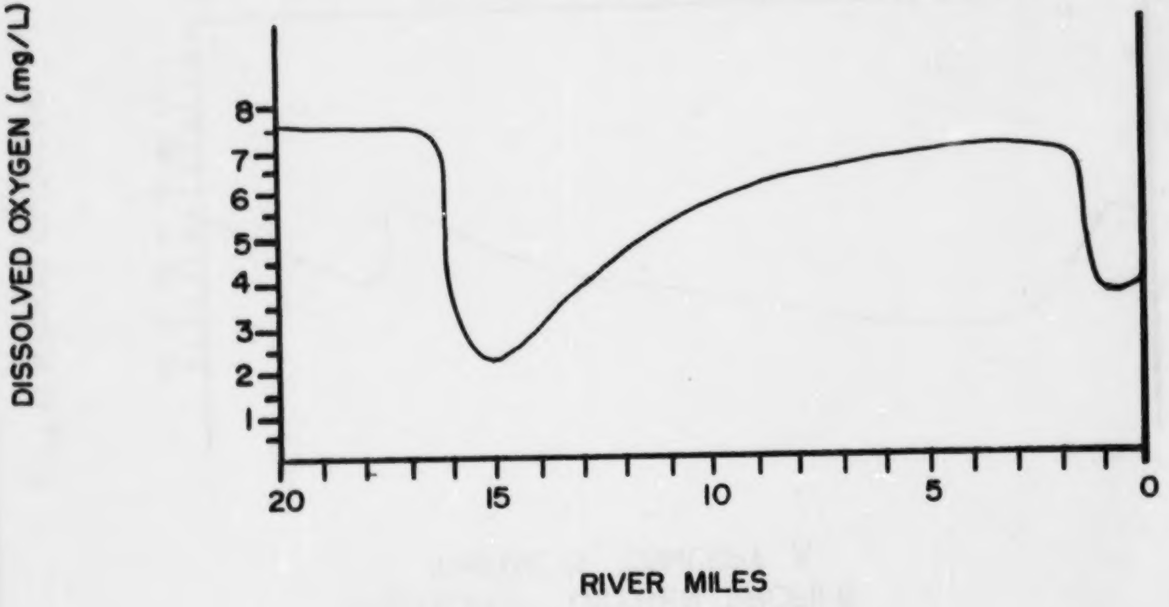


FIGURE V-26
SIMS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

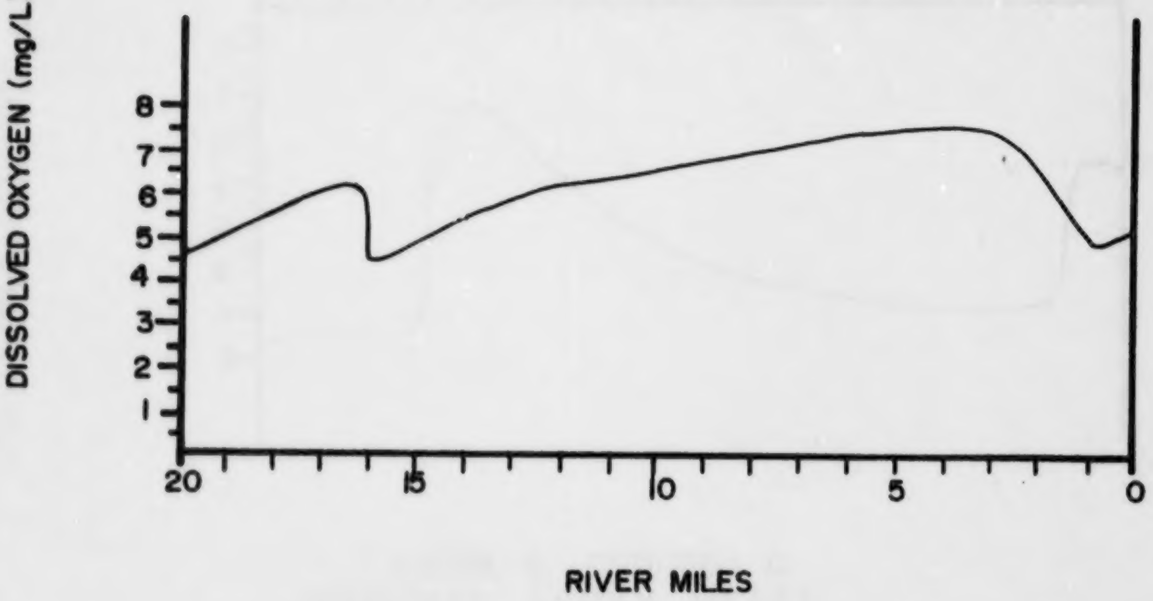


FIGURE V-27
VINCE BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

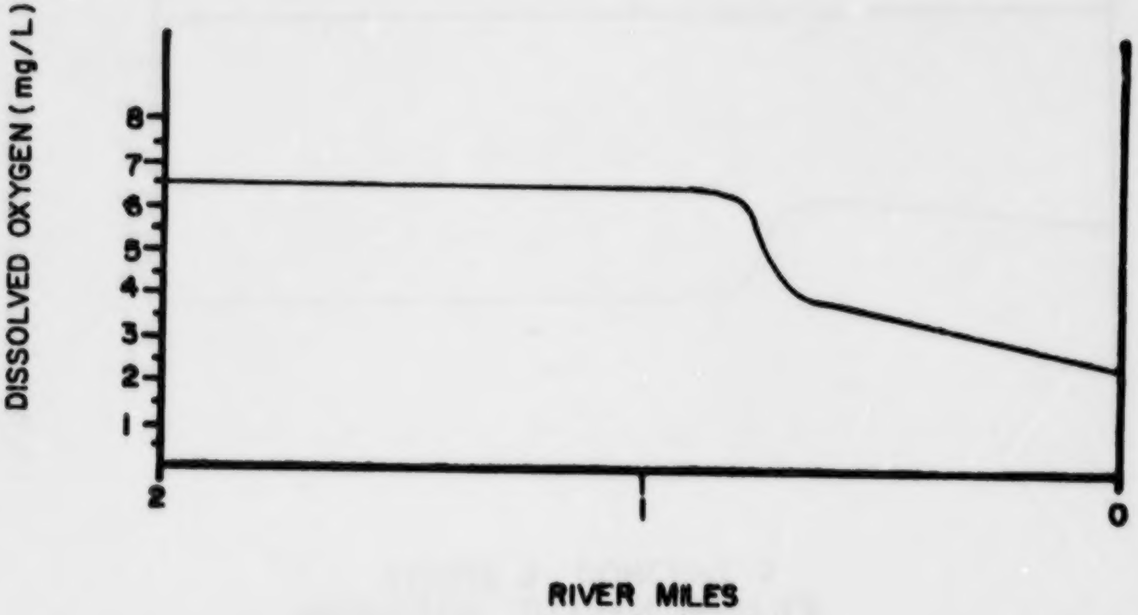


FIGURE Ⅴ- 28
VINCE BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

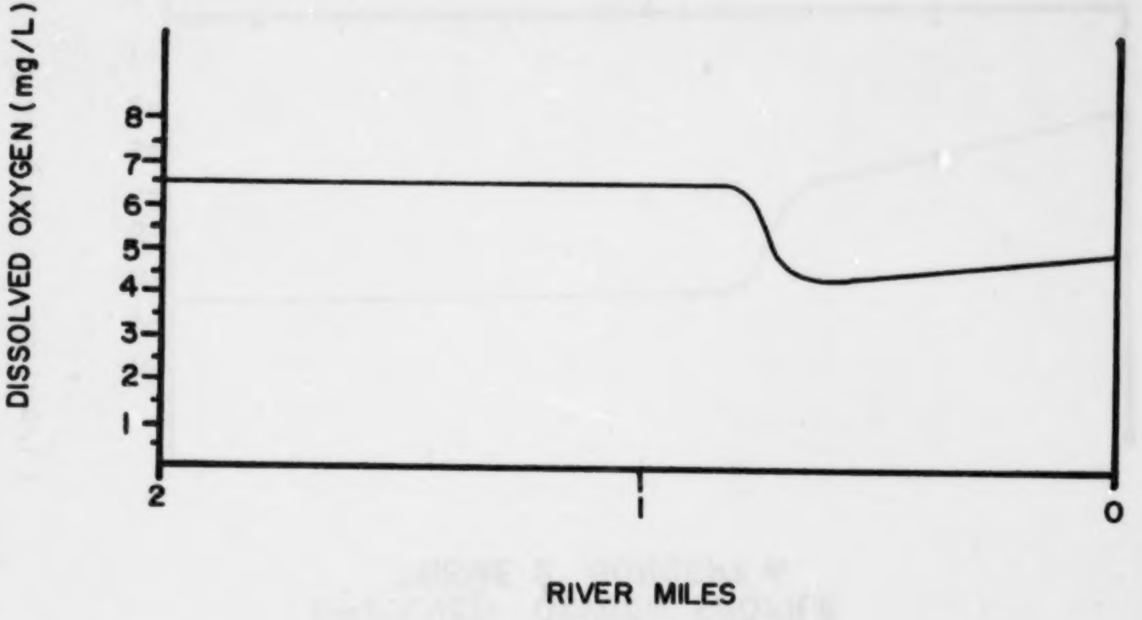


FIGURE V-29
HUNTING BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

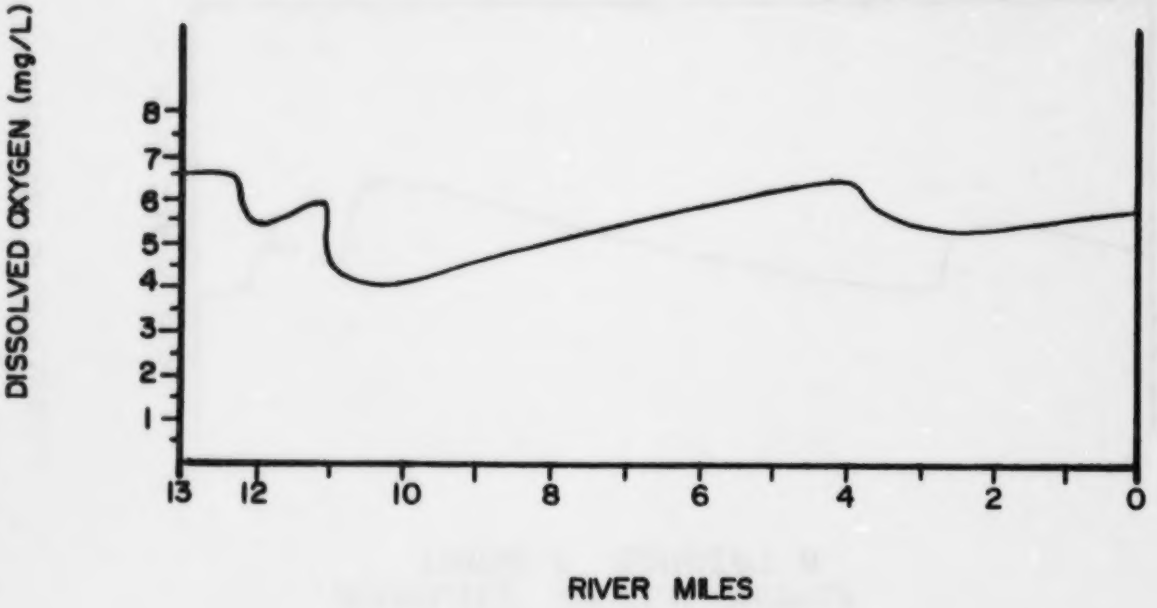


FIGURE V-30
HUNTING BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

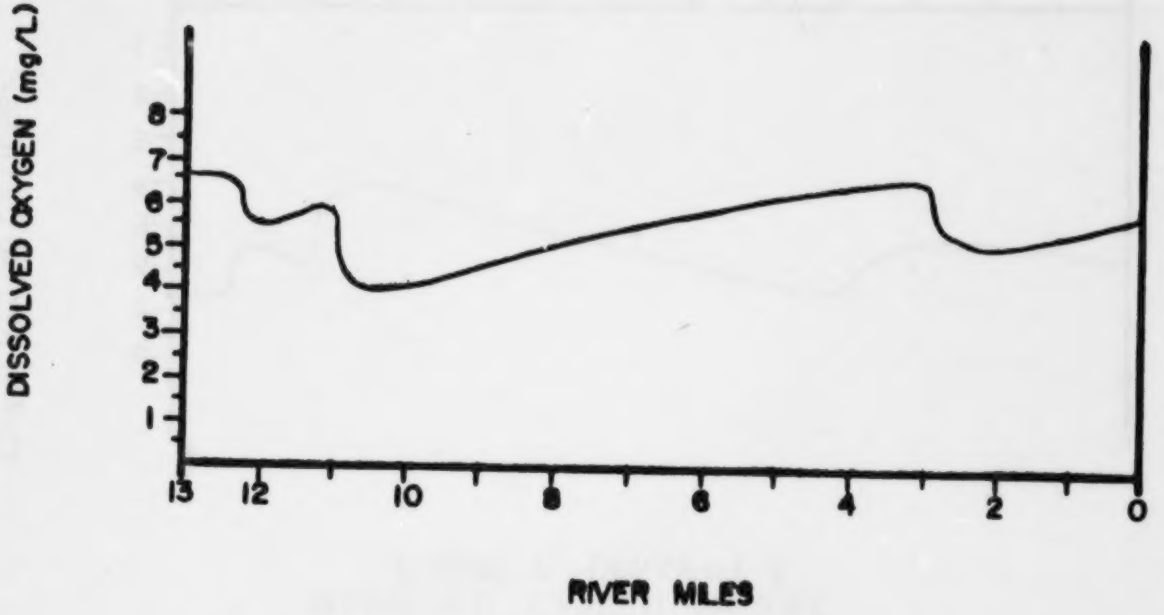


FIGURE V- 32
HUNTING BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

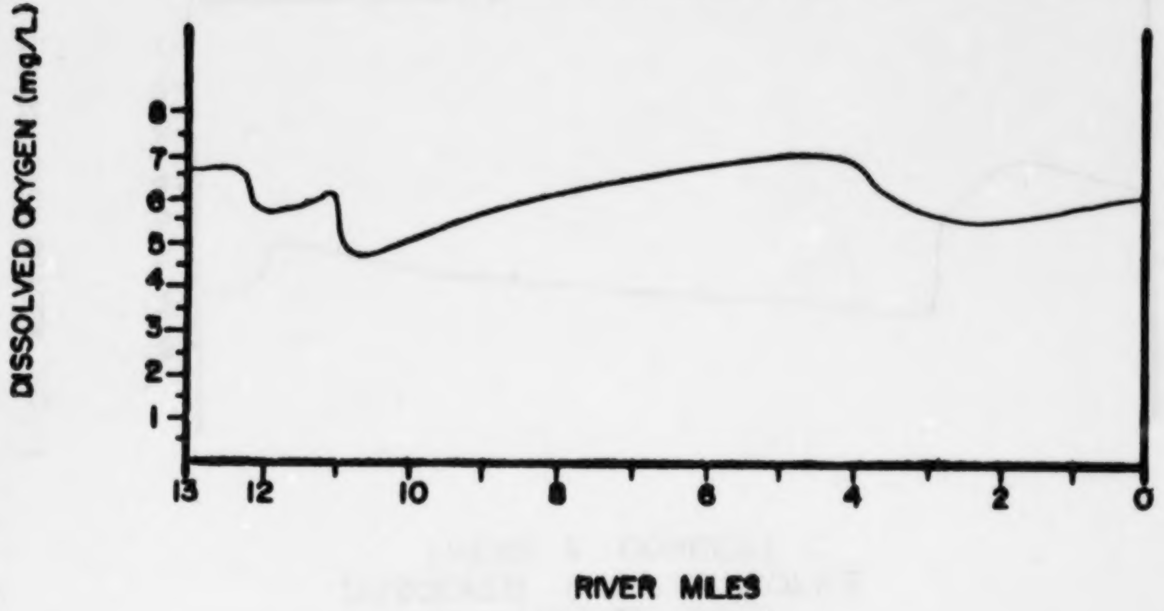


FIGURE V-31
HUNTING BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

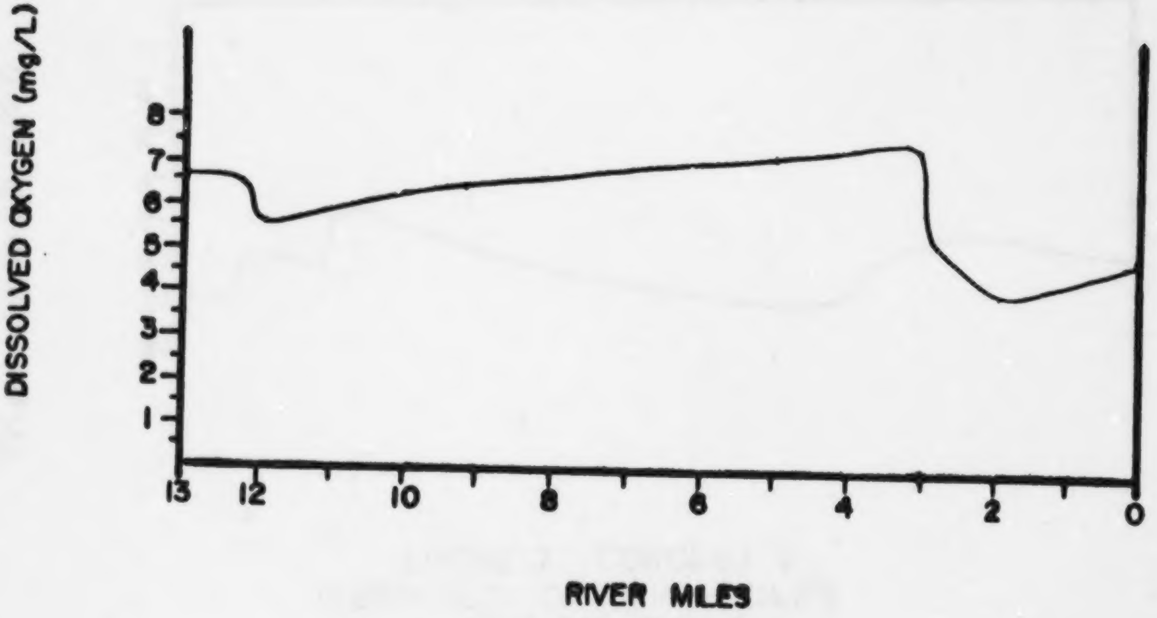
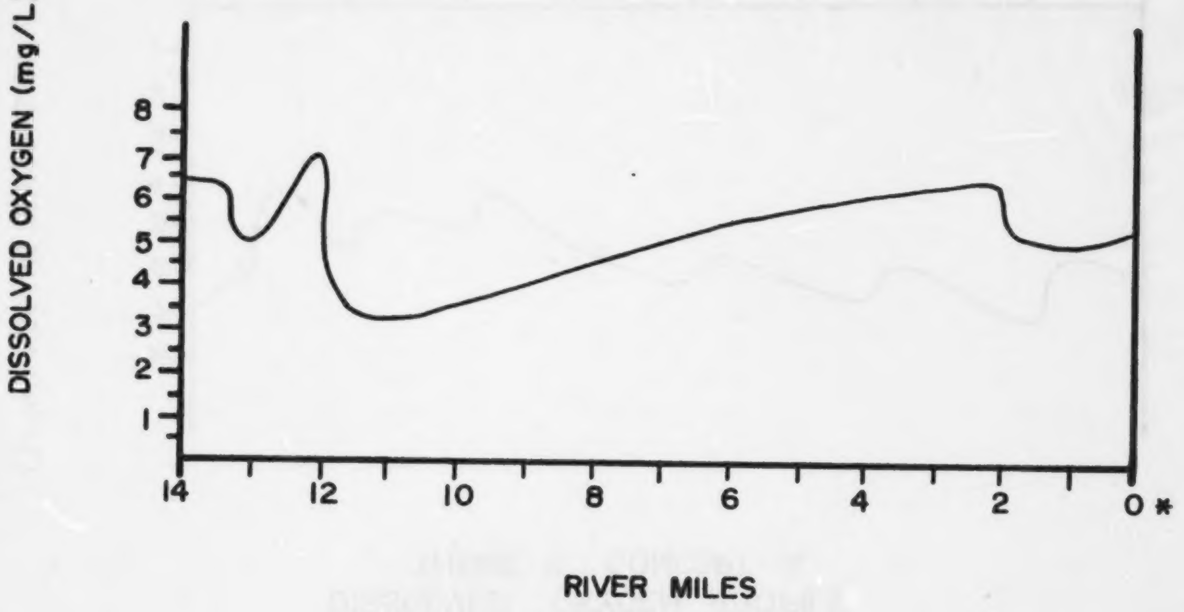


FIGURE V-33A
HALLS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A



* MILE 0.0 HALLS BAYOU = MILE 11.8 GREENS BAYOU

FIGURE V-33B
GREENS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

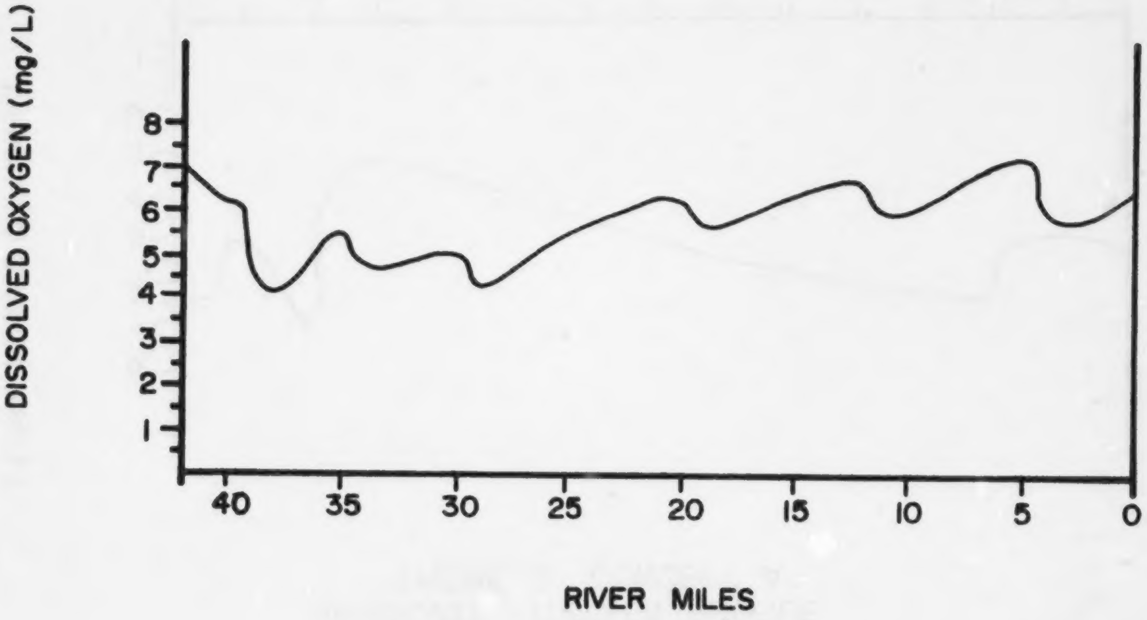
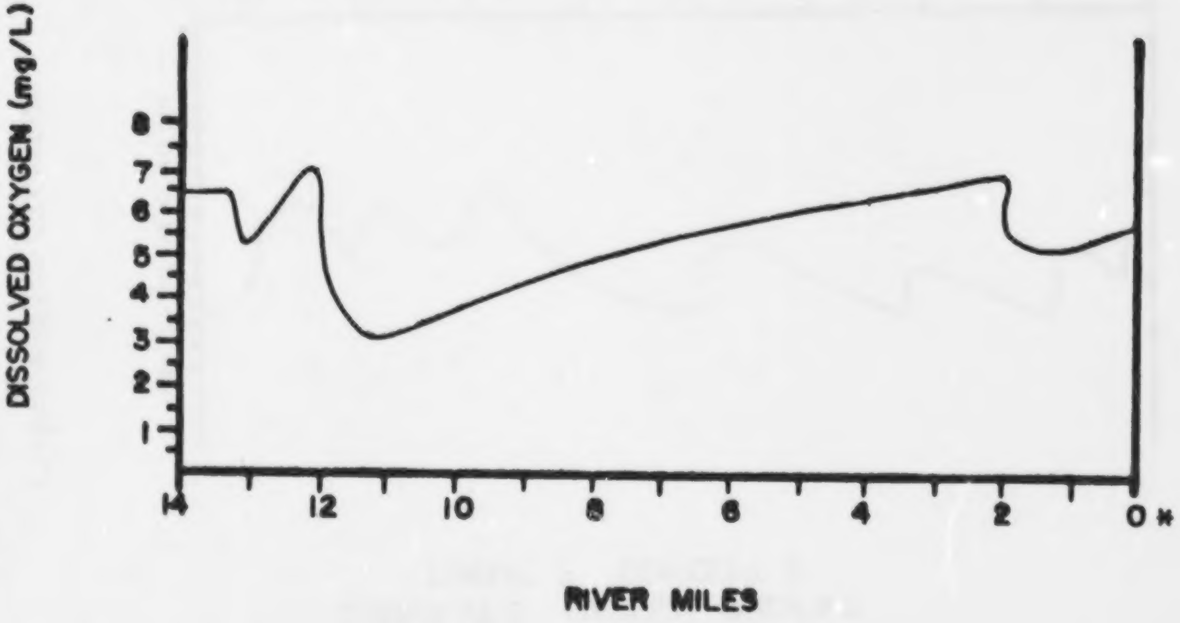


FIGURE V-34A
HALLS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B



* MILE 0.0 HALLS BAYOU =
MILE 11.8 GREENS BAYOU

FIGURE V-34B
GREENS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

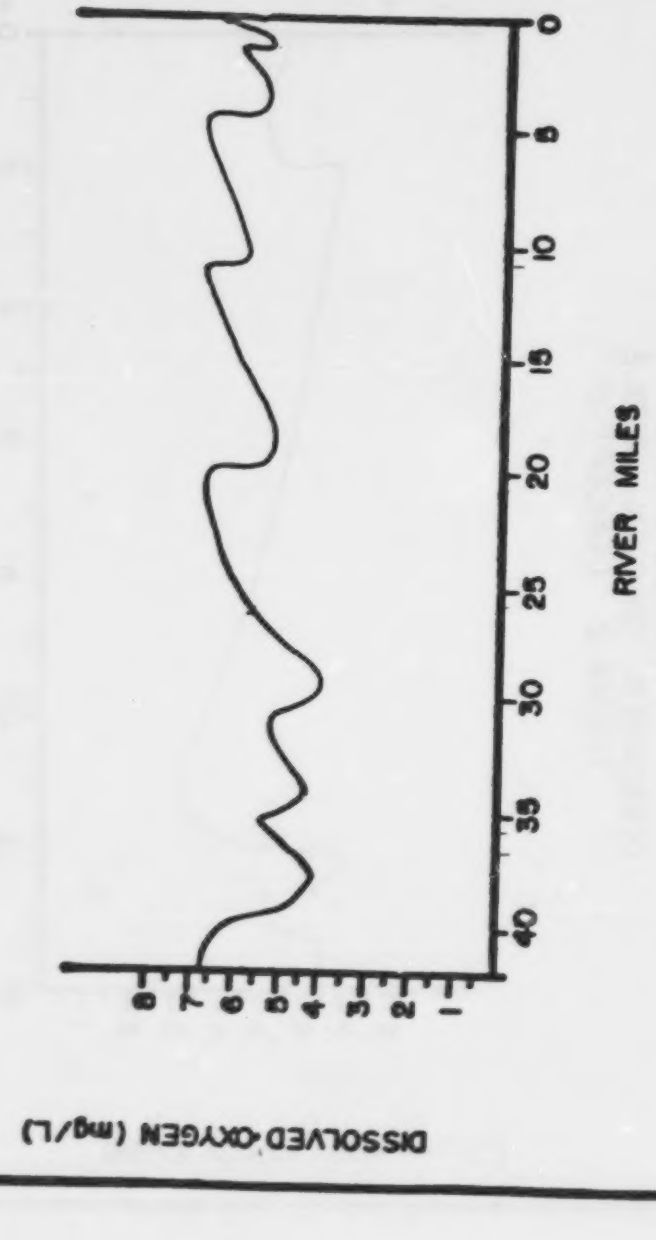
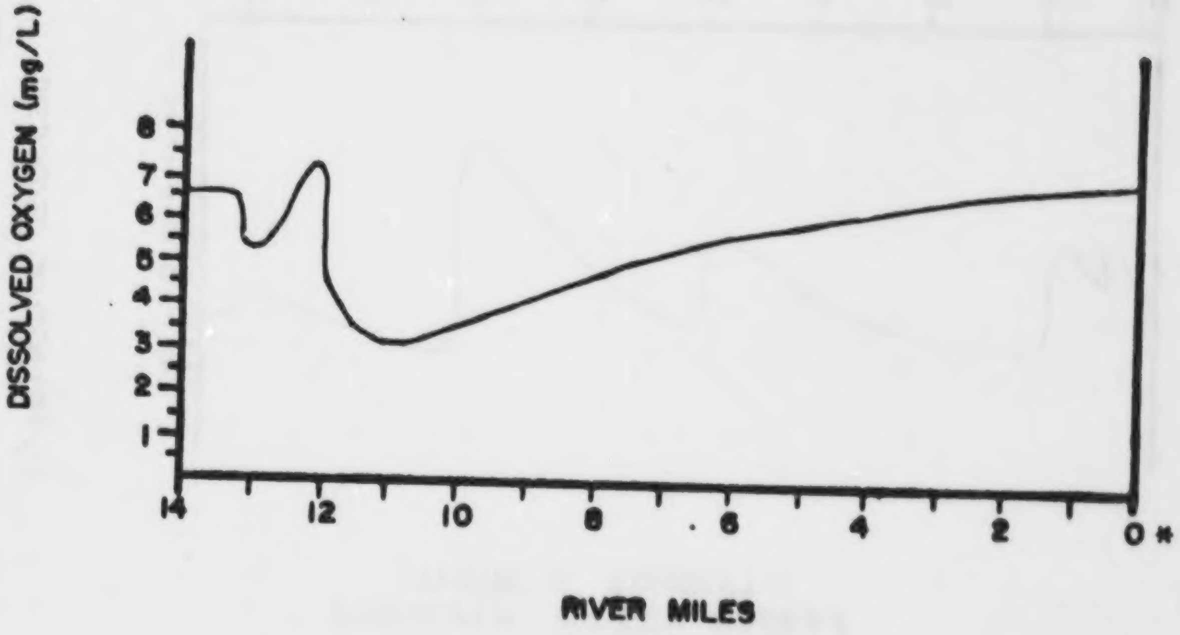


FIGURE V-35A
HALLS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C



* MILE 0.0 HALLS BAYOU =
MILE 11.8 GREENS BAYOU

FIGURE V-35B
GREENS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

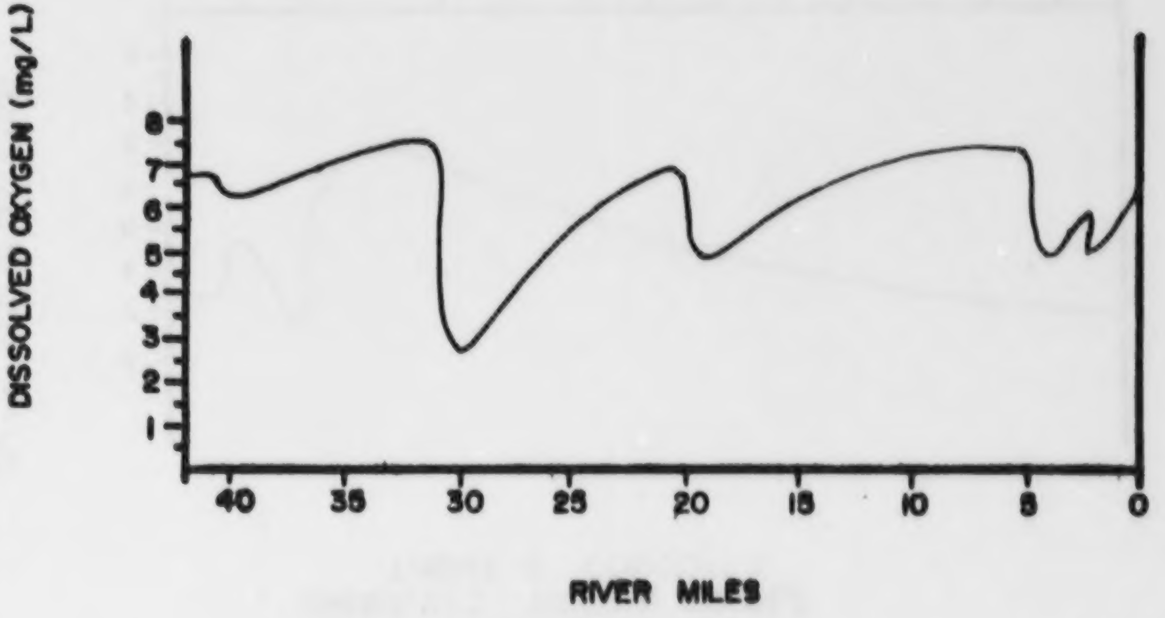
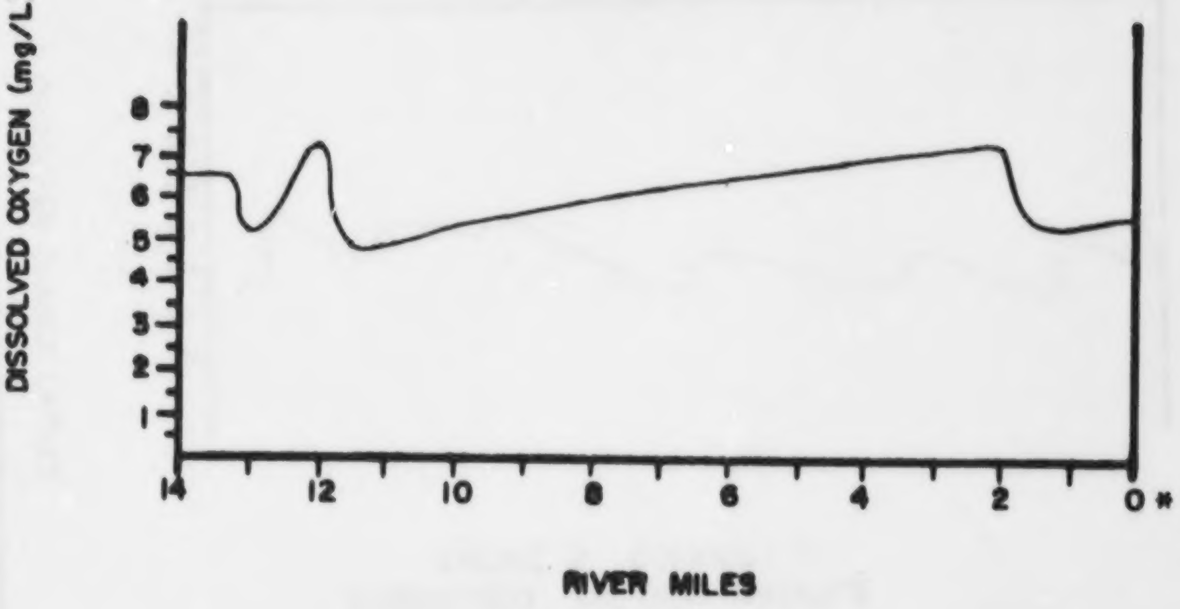


FIGURE V-36A
HALLS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A



* MILE 0.0 HALLS BAYOU =
MILE 11.8 GREENS BAYOU

FIGURE V-36B
GREENS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

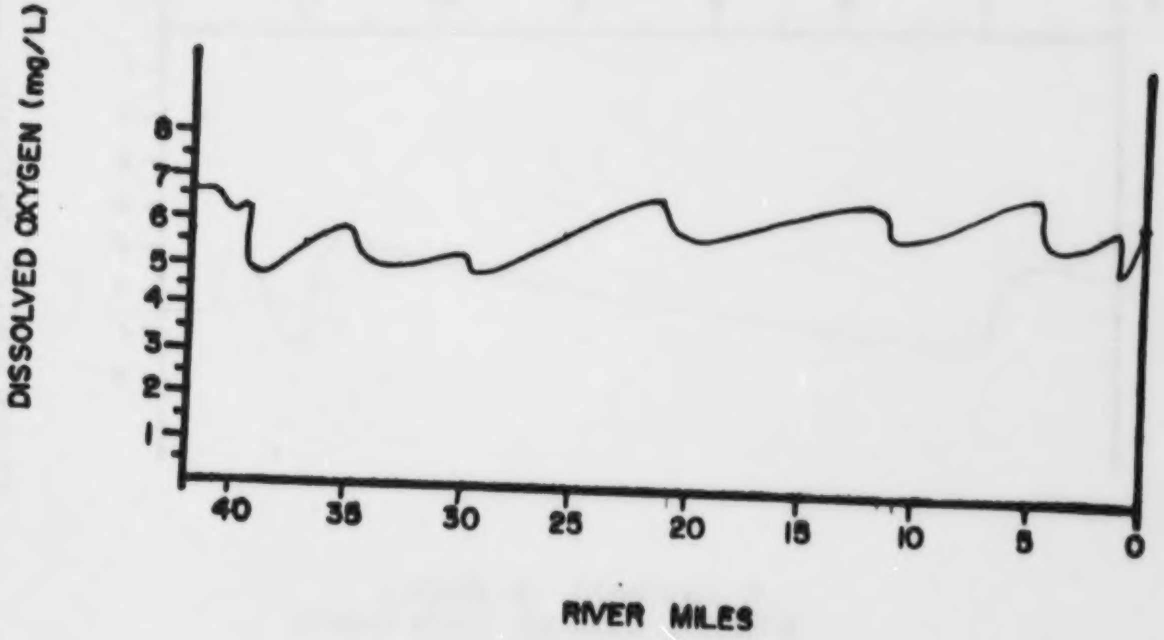


FIGURE Ⅴ-37
CARPENTERS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT A

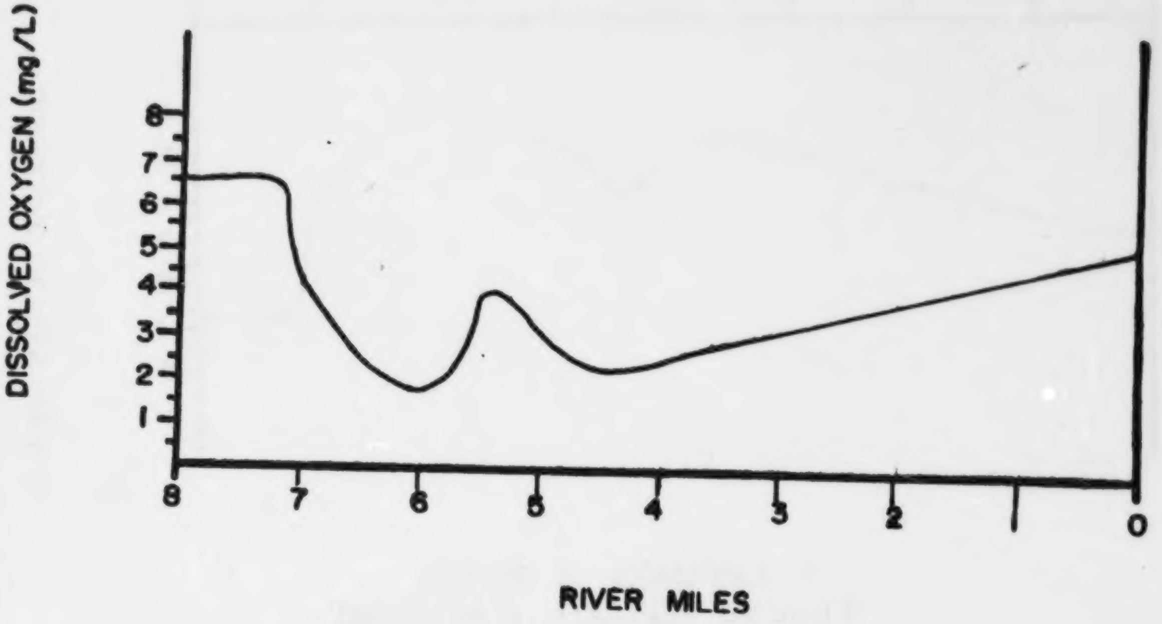


FIGURE V-38
CARPENTERS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT B

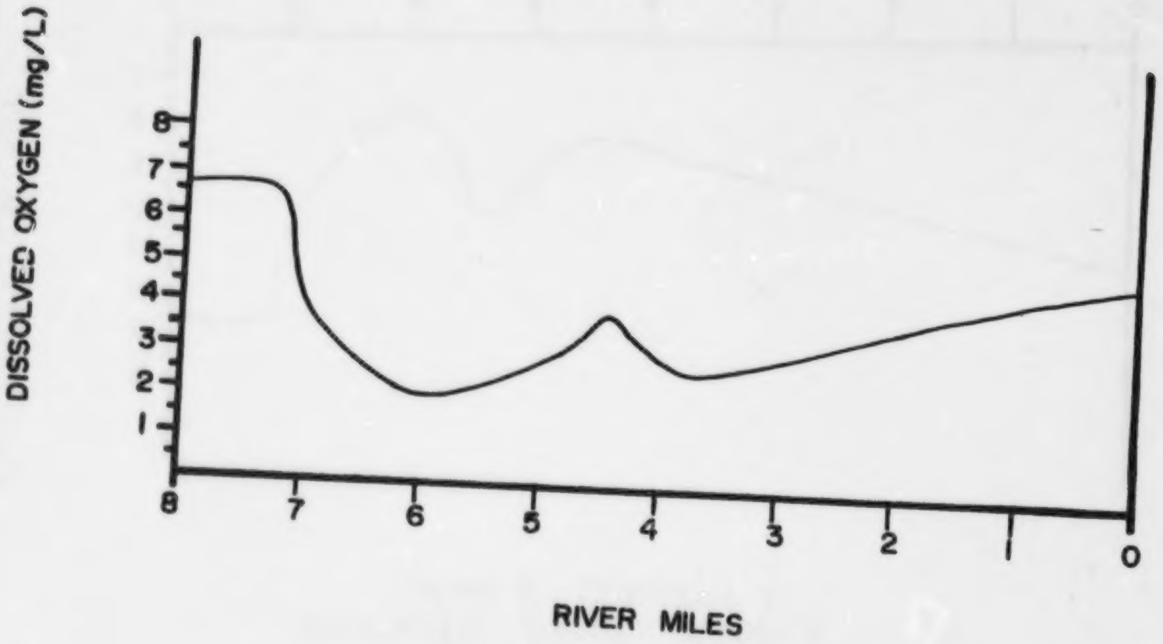


FIGURE V-39
CARPENTERS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 2 CONCEPT C

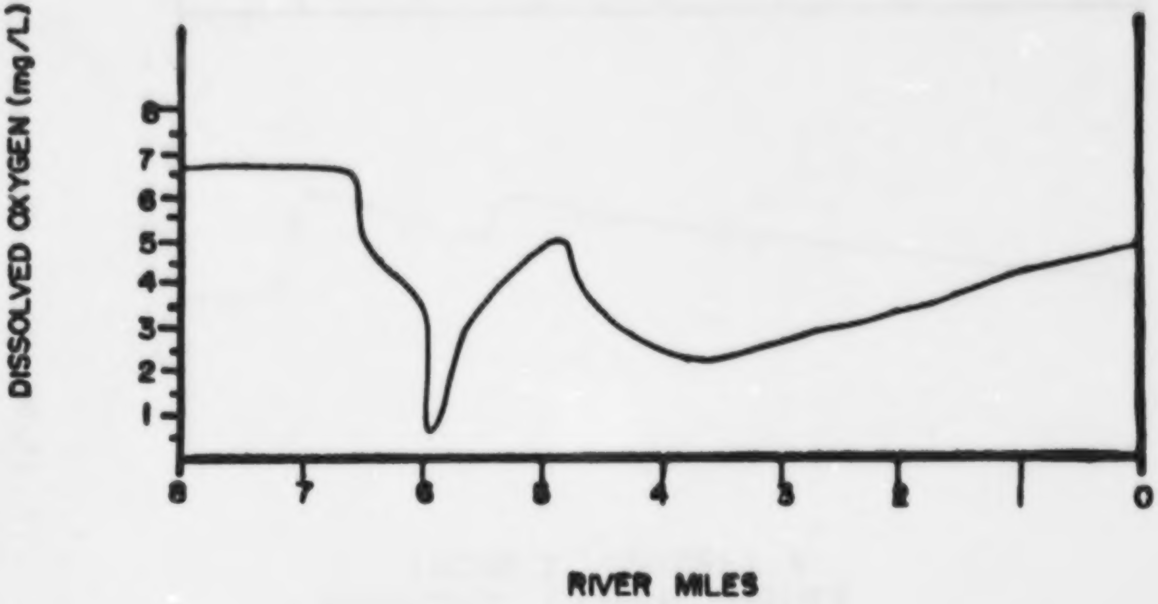


FIGURE V-40
CARPENTERS BAYOU
DISSOLVED OXYGEN PROFILE
THEME 3 CONCEPT A

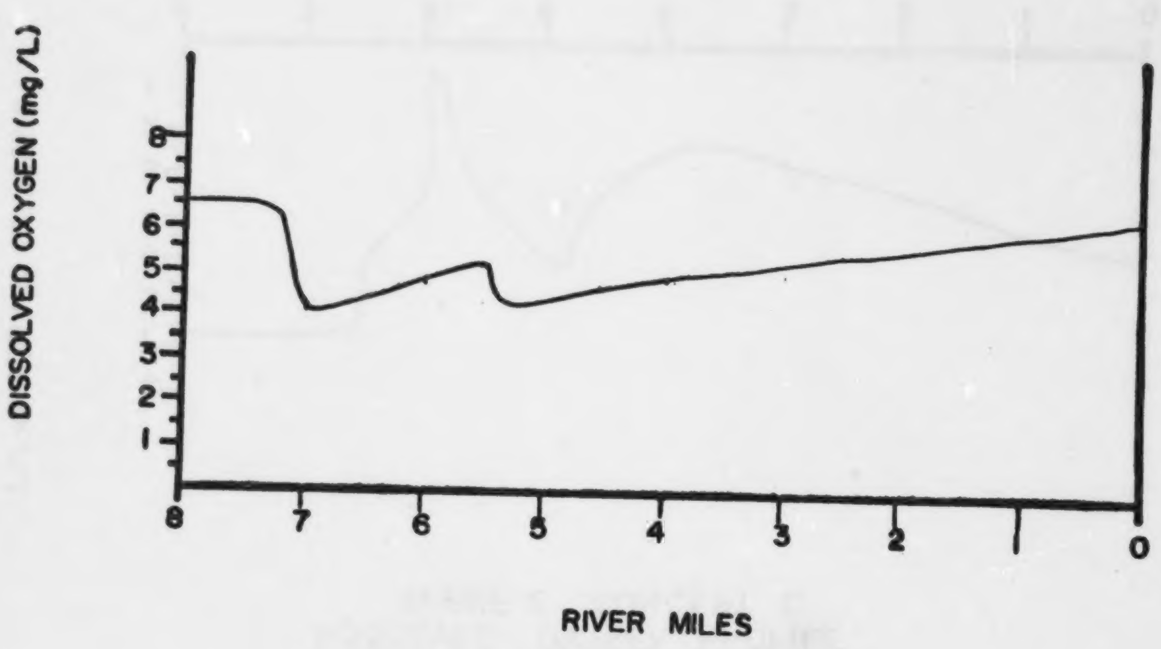


FIGURE VI-1
HOUSTON SHIP CHANNEL
SEGMENT 1005
DISSOLVED OXYGEN VS RIVER MILE
THEME I CONCEPT A

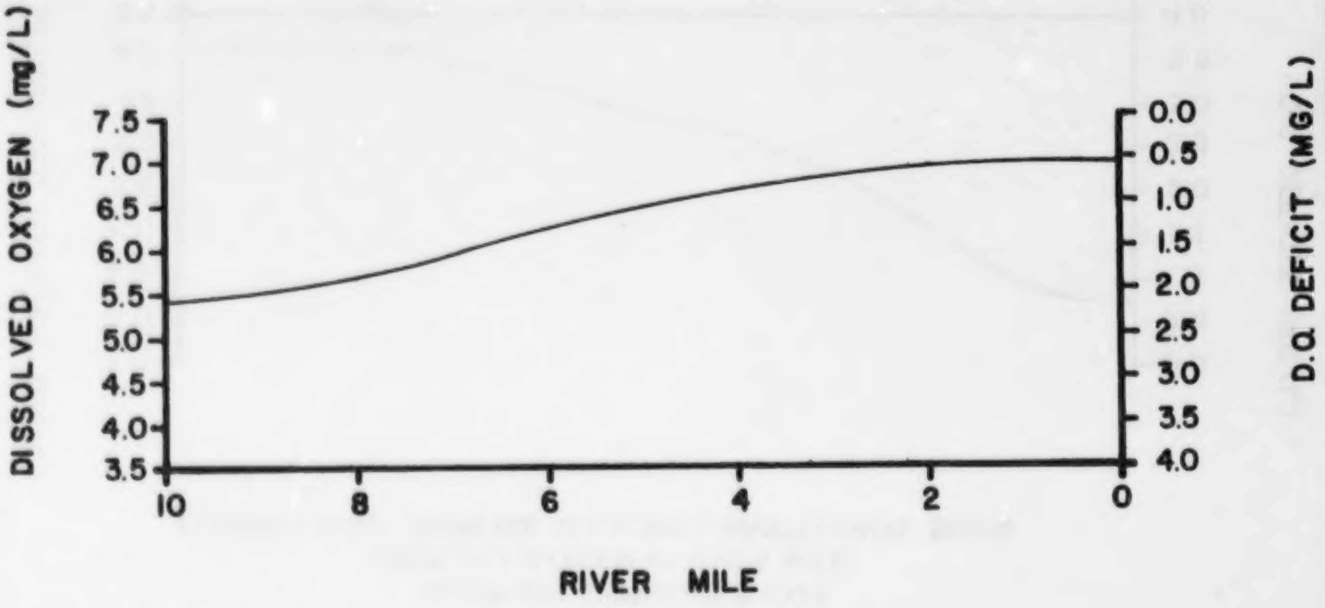


FIGURE VI-2
HOUSTON SHIP CHANNEL
SEGMENTS 1005, 1006 & 1007
DISSOLVED OXYGEN VS RIVER MILE
SEGMENT 1005 - INCREASE ALLOCATED WASTELOADS 300%

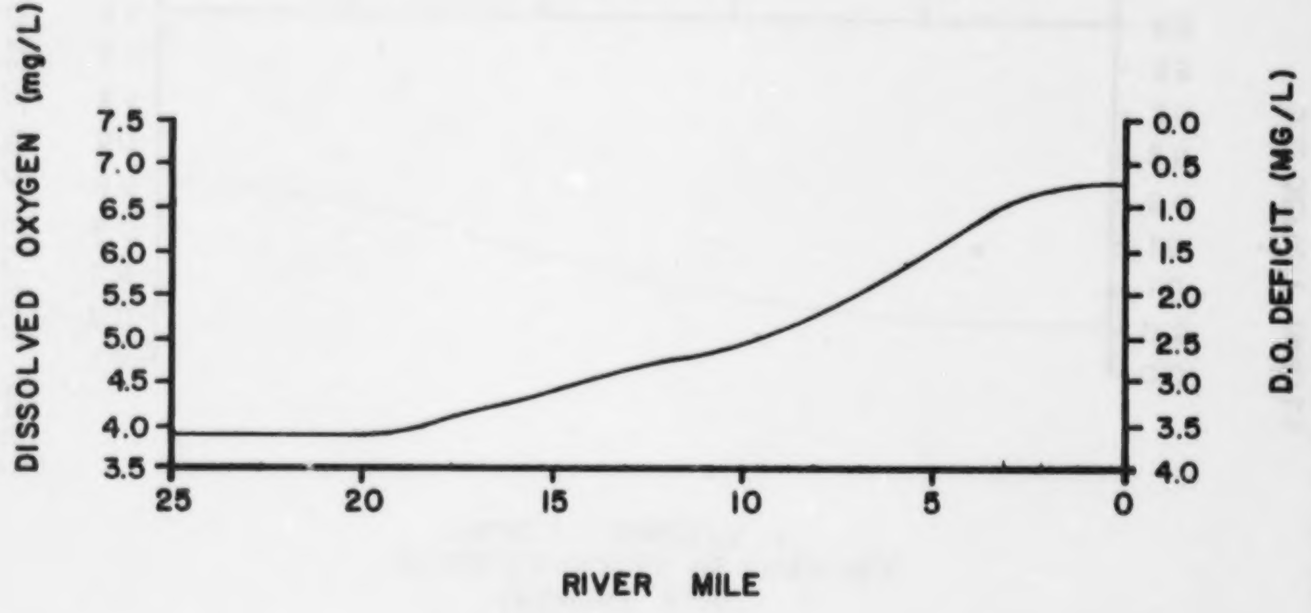


FIGURE VI-3
HOUSTON SHIP CHANNEL
SEGMENTS 1005, 1006 & 1007
DISSOLVED OXYGEN VS RIVER MILE
INCREASE ALLOCATED WASTELOADS / INSTREAM AERATION

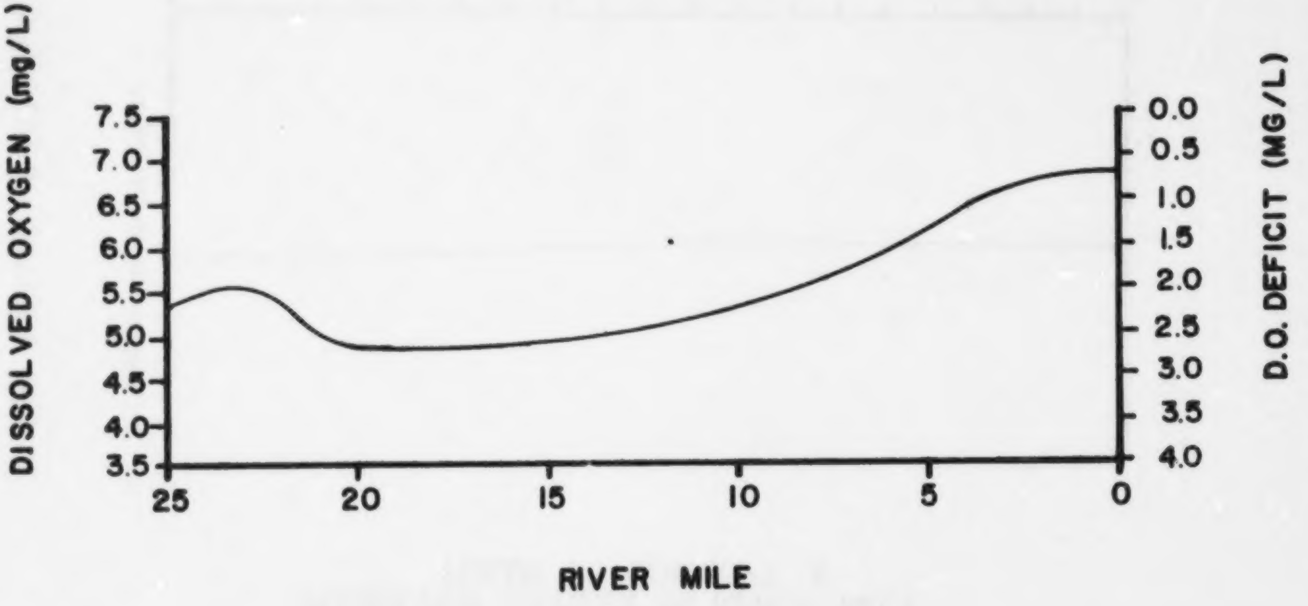


FIGURE VI-4
SAN JACINTO RIVER-TIDAL
DISSOLVED OXYGEN VS RIVER MILE
THEME I CONCEPT A

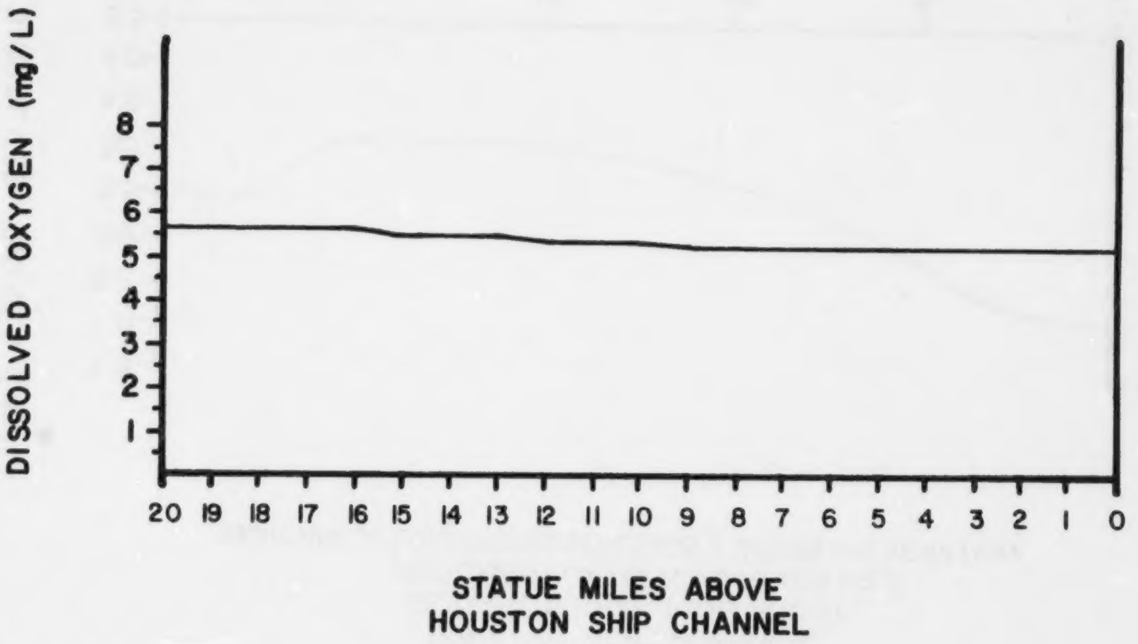


FIGURE VI-5
SAN JACINTO RIVER
DAY 20
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

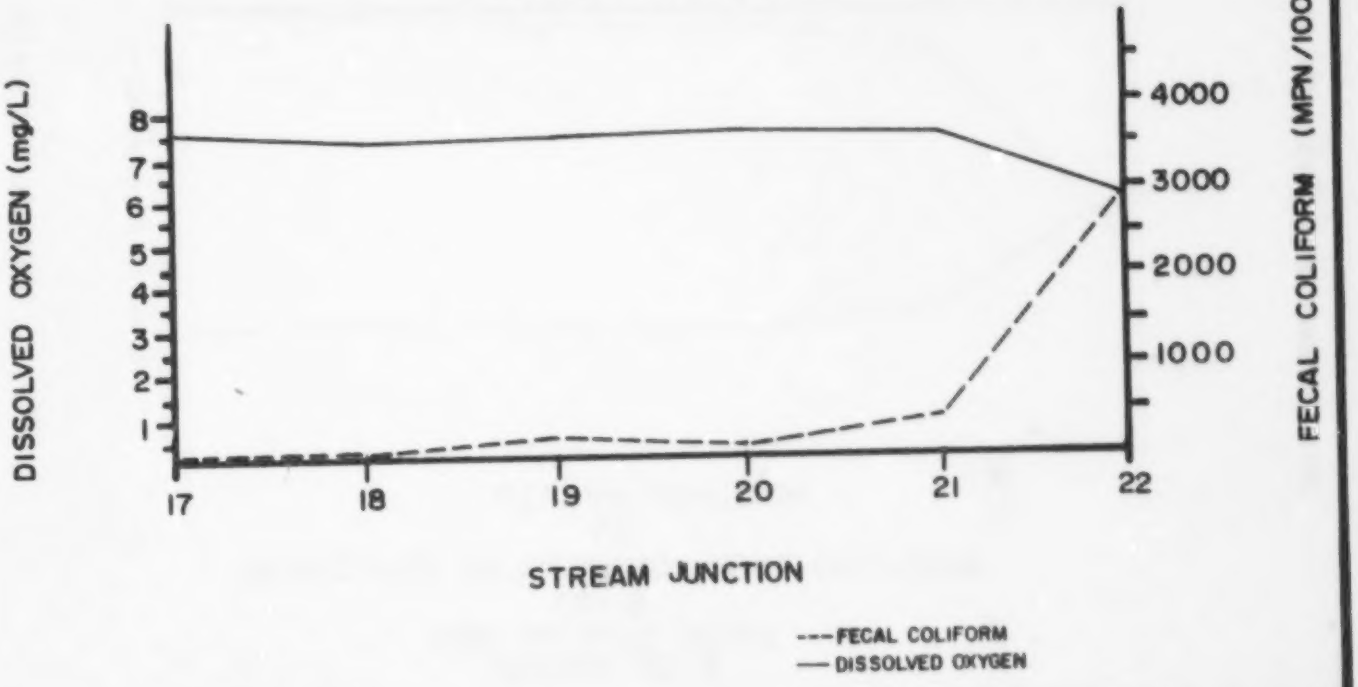


FIGURE VI-6
SAN JACINTO RIVER
DAY 9
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

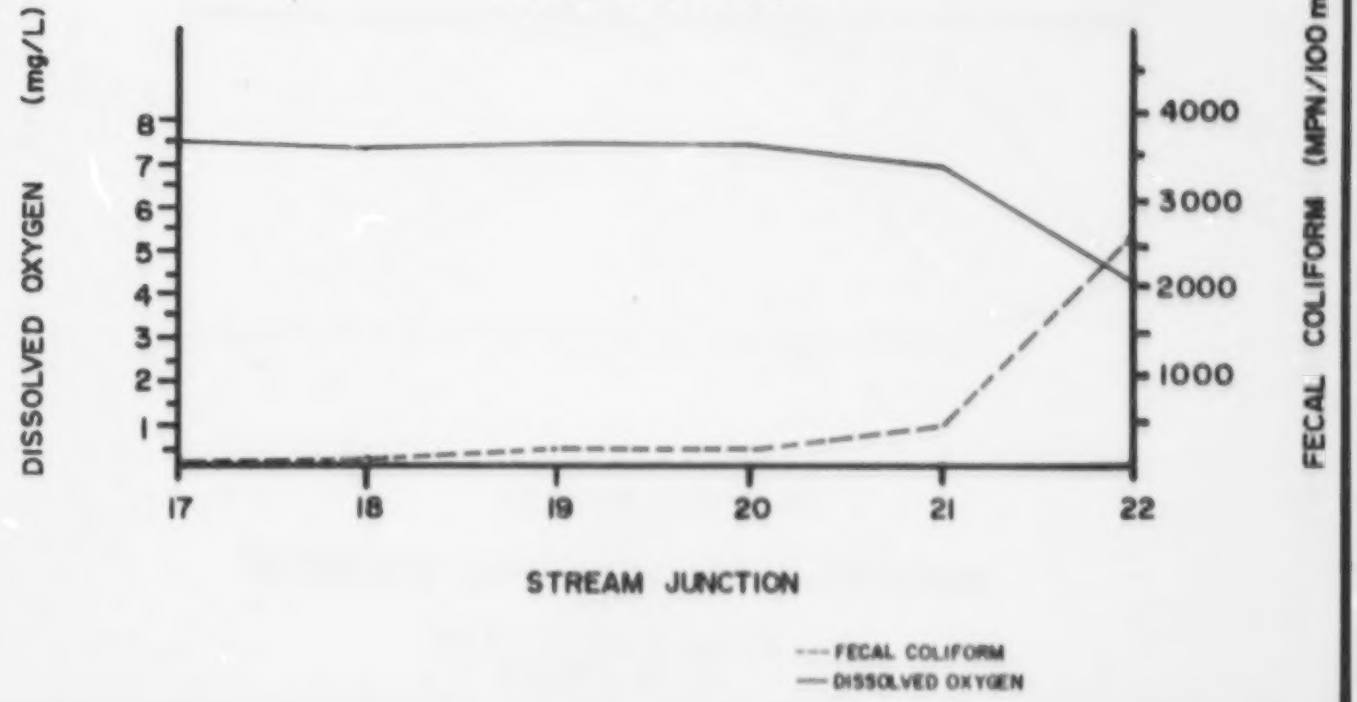


FIGURE VII-7
SAN JACINTO RIVER
DAY 20
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

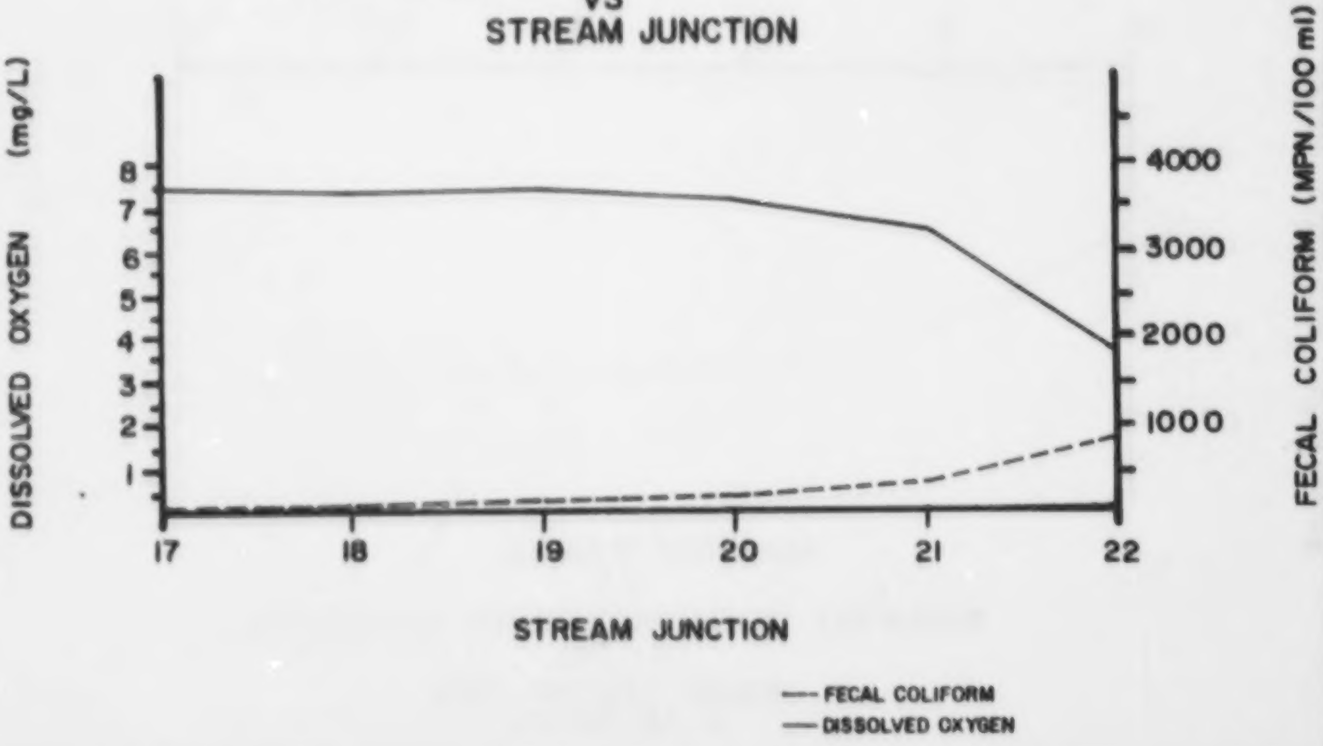


FIGURE VI-8
SAN JACINTO RIVER
DAY 15
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION

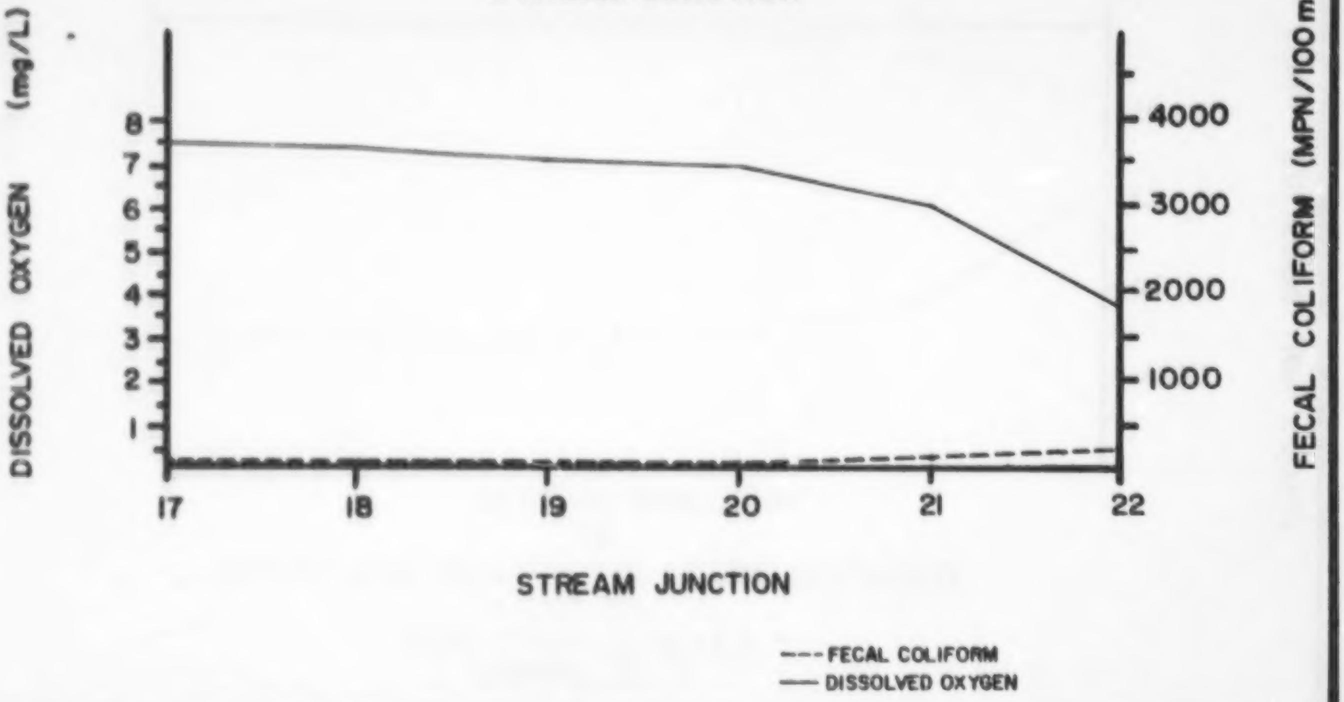
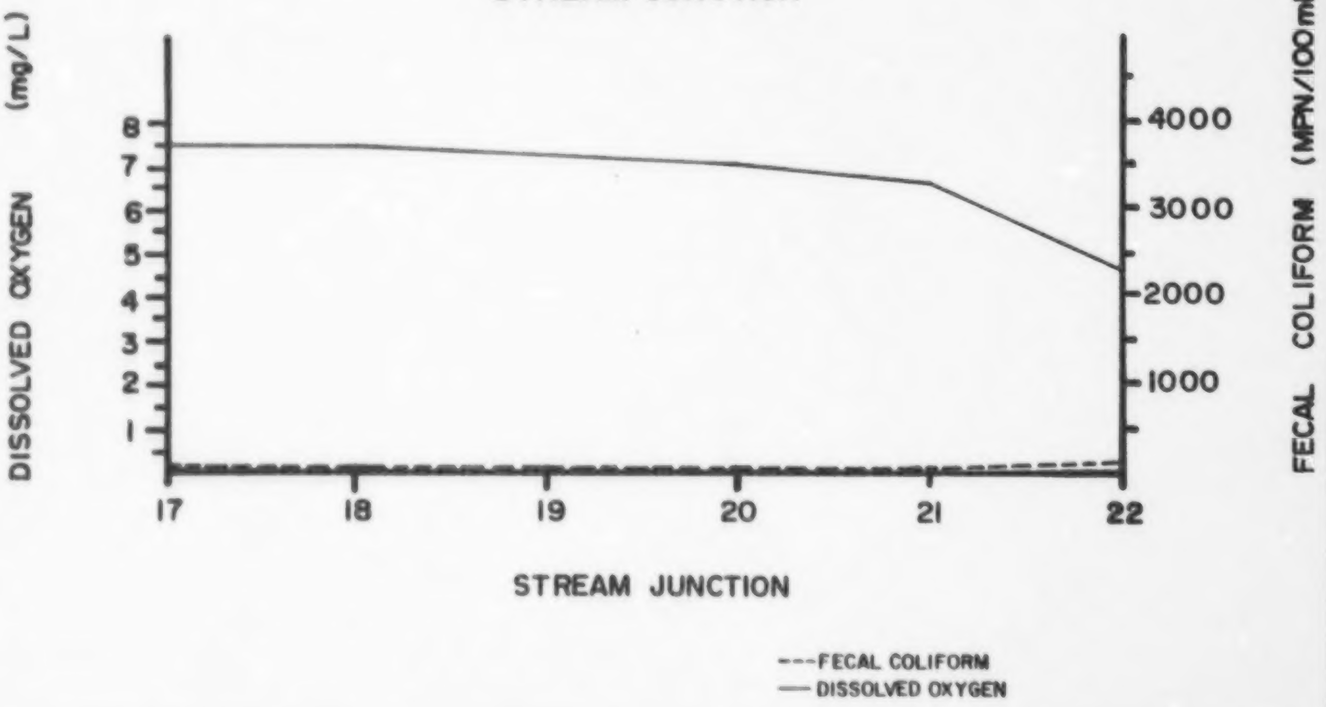


FIGURE VI-9
SAN JACINTO RIVER
DAY 20
DISSOLVED OXYGEN AND FECAL COLIFORM
VS
STREAM JUNCTION



APPENDIX C

RELATIVE COSTS OF VARIOUS LEVELS OF TREATMENT AND REGIONALIZATION

APPENDIX C - RELATIVE COSTS OF VARIOUS LEVELS OF TREATMENT AND REGIONALIZATION

Introduction

As part of the existing 208 report, certain decisions and recommendations were made on the degrees of treatment required for various basins and plants. These were made based on stream water quality impacts as compared to costs based on present worth analyses. While this is a legitimate, highly utilized planning tool, most area citizens can more readily relate to an annual cost. Therefore, data are presented herein to show relative costs for various degrees of treatment. It must be emphasized that these costs are not to be equated to user charges nor do they include all costs applicable to sewage treatment.

As well as recommending the level of treatment to be utilized, the 208 process also evaluated various degrees of regionalization. In most cases, some degree of regionalization was shown to have economic incentives based on present worth analyses. Unfortunately, the 208 area has in excess of 300 domestic dischargers. Thus, rigorous examination of the regionalization concept for the entire area is not possible. Therefore, various examples of regionalization schemes are presented herein to indicate possible economic incentives. Again, it must be stressed that the costs proposed cannot be equated to a user charge.

Common Assumptions

The following assumptions and methods are common to all of the calculations presented.

1. New capital costs are amortized for 30 years at seven percent.
2. Treatment plant, conveyance system, and operation and maintenance costs are taken from previously cited material.
3. All costs are based on 1975 dollars.
4. Operation and maintenance costs other than treatment plant, sludge disposal, collection system and conveyance system operation and maintenance are ignored.
5. Land costs are $10,000/acre.

Alternative Levels of Effluent Quality

General

While many classes of alternative levels of effluent quality were investigated through the study, two are most important:

1. Various levels of oxygen demanding material.
2. Treatment with and without phosphorous removal.

The following assumptions are made in addition to the common assumptions listed above:

1. All plants operate at one hundred percent of capacity.
2. No provisions are made for federal grants to offset capital costs.
3. Collection costs are taken into account but no conveyance costs.

Alternative Levels of Oxygen Demanding Materials

Levels and Sizes Addressed. The following levels of effluent quality are investigated:

Effluent Set	Effluent Quality		
	BOD (mg/l)	NH_3 as Nitrogen (mg/l)	Total Ultimate Oxygen Demand (mg/l)
2	10	8*	52
3	5	8*	44
4	5	8*	44
2N	10	5	38
3N	5	5	30
4N	5	3	21

*Estimated, not a requirement.

Plants of the size 0.5 MGD, 1.0 MGD, 5.0 MGD, and 10.0 MGD are investigated.

Cost Data. Cost data are presented in detail in Tables C-1 through C-6 and summarized below:

Effluent Set	Unit Cost ($/1000 gpd/year)			
	0.5 MGD	1.0 MGD	5.0 MGD	10.0 MGD
2	$ 320	$ 298	$ 232	$ 214
3	418	325	245	225
4	458	349	261	237
2N	468	353	260	235
3N	492	379	275	246
4N	546	405	284	257

Discussion

Data presented above indicates that when considering small plants, increases in cost are rather dramatic when more stringent effluent requirements are met. However, with larger plants, the increases are not nearly as significant.

Another method of comparison is the cost/mg/1 ultimate oxygen demanding material removed. Raw sewage has an ultimate oxygen demand of 435 mg/1. Therefore, values are as follows:

Effluent Set	Removal Cost (Unit Cost/mg/1 ultimate oxygen demand removed)			
	0.5 MGD	1.0 MGD	5.0 MGD	10.0 MGD
2	$ 0.84	$ 0.78	$ 0.61	$ 0.56
3	1.07	0.83	0.63	0.58
4	1.17	0.89	0.67	0.61
2N	1.18	0.89	0.65	0.59
3N	1.21	0.94	0.68	0.61
4N	1.32	0.98	0.69	0.62

The above data indicate that operating plants at various effluent sets may be advantageous. For example, assume that four plants at 0.5 MGD each are all discharging into the same stream at points so close that, for water quality simulation purposes, they are identical. Further assume that the stream can accept 640 pounds ultimate oxygen demand in that section. The ultimate oxygen demand can be met in several ways:

Option 1 - All plants at 2N. Ultimate oxygen demand of 640 lbs/day.

Option 2 - Two plants at effluent set 2, two plants at effluent set 4N. Ultimate oxygen demand of 620 lbs/day.

Option 3 - One plant at effluent set 2, three plants at effluent set 3N. Ultimate oxygen demand of 590 lbs/day.

Annual costs for the four plants are then as follows:

Option	Annual Cost
1	$936,000
2	872,000
3	901,000

As shown above, savings of $64,000 could be achieved by utilizing variable levels of treatment. To equitably utilize this methodology, some means of cost spreading between service areas would be required.

Phosphorus Removal

Levels and Sizes Addressed. The following effluent sets are investigated:

Effluent Set	Effluent Quality		
	BOD_5 (mg/l)	NH_3 as Nitrogen (mg/l)	Phosphorus pH (mg/l)
3N	5	5	-
4N	5	5	-
3NP	5	5	2
4NP	5	3	1

Plant sizes of 0.5 MGD, 1.0 MGD, 5.0 MGD, and 10.0 MGD are investigated.

Cost Data. Cost data are presented in Tables C-5, C-6, C-7 and C-8 and summarized below:

Effluent Set	Unit Cost ($/1000 gpd/year)			
	0.5 MGD	1.0 MGD	5.0 MGD	10.0 MGD
3N	492	379	275	246
4N	546	405	284	257
3NP	554	426	306	273
4NP	608	452	314	284

Discussion

The incremental cost of phosphorus removal are as follows:

Plant Size	Incremental Cost
0.5 MGD	$62/1000 gpd/year
1.0 MGD	$47/1000 gpd/year
5.0 MGD	$31/1000 gpd/year
10.0 MGD	$27/1000 gpd/year

Utilizing an average of $35/1000 gpd/year, savings inherent in dropping the phosphorus requirement for Clear Creek and Clear Lake will be approximately $600,000/year based on estimated 1995 population. In larger size plants (5.0 MGD or greater), the incremental phosphorus cost is approximately the same as the incremental cost of going from effluent set 2 to effluent set 2N and less than the incremental cost of going from effluent set 2N to effluent set 4N.

Alternative Levels of Regionalization

General

Several different examples for regionalization are examined for each. It is assumed that 10 MGD of wastewater must be treated. Various plant sizes are investigated to provide the 10 MGD capacity:

- 20 plants of 0.5 MGD each
- 10 plants of 1.0 MGD each
- 2 plants of 5.0 MGD each
- 1 plant of 10.0 MGD

The examples utilized are:

- No treatment capacity is existing. All required facilities are built simultaneously and operate at capacity immediately.
- No treatment capacity is existing. Required facilities are phased.
- Treatment capacity is existing in the form of eight plants at 0.5 MGD each. Required facilities are phased.

Levels of Treatment Addressed

Cost data are presented for effluent set 2N plants.

Regionalization Systems

The following regionalization systems are investigated:

Plant		Conveyance	
Size	Number	Description	Cost
0.5 MGD	20	None	$0
1.0 MGD	10	Ten 0.5 MGD Lift Stations Ten miles force main	$150,000/plant $1.500,000 total
5.0 MGD	2	Eight 0.5 MGD Lift Stations Eight 1.0 MGD Lift Stations One 2.5 MGD Lift Station Twenty miles force main	$1,840,000/plant $3,680,000 total
10.0 MGD	1	Eight 0.5 MGD Lift Stations Eight 1.0 MGD Lift Stations Two 4.5 MGD Lift Stations One 4.5 MGD Lift Station Twenty miles force main	$4,020,000/plant $4,020,000 total

Common Assumptions

Common assumptions are the same as those presented in the Introduction to Appendix C, with the following additions:

1. Land costs for lift stations and force mains are inconsequential.
2. No provisions are made for federal grants to offset capital costs except where stated.

3. Operation and maintenance costs for plants operating below capacity are estimated assuming seventy-five percent of annual costs are fixed and twenty-five percent vary directly with flow.

All plants Built Simultaneously

General. This example assumes that all required facilities are built at the same time and operate at design capacity immediately.

Cost Data. Cost data are presented in Table C-9. For simplicity, costs are presented for a single plant.

Effects of Federal Participation. Cost data developed assuming a seventy-five percent federal grant for plants and conveyance are presented in Table C-10.

Discussion. Cost data are summarized below:

Regional Plant Size (MGD)	Unit Cost ($/1000 gpd/year) With Federal Participation	Unit Cost ($/1000 gpd/year) Without Federal Participation
0.5	356	468
1.0	290	372
5.0	240	305
10.0	227	284

As shown above, regionalization has the potential to result in significant savings.

Plants Phased - No Existing Capacity

General. This example assumes that no plants presently exist but that new facilities can be phased to meet the following capacity requirements:

Time	Capacity Required
0 years	2 MGD
2 years	4 MGD
4 years	6 MGD
6 years	8 MGD
8 years	10 MGD
10-20 years	10 MGD

Construction Schedules. The following construction schedules are utilized for plants:

Year	Number of Plants Built for Various Systems 20 at 0.5 MGD	10 at 1.0 MGD	2 at 5.0 MGD	1 at 10.0 MGD
0	4	4	2	1
2	4	4	0	0
4	4	2	0	0
6	4	0	0	0
8	4	0	0	0

Twenty percent of the collection and conveyance costs are incurred for each year cited above.

Cost Data. Inflation is ignored in the cost analysis. Data are presented below:

Year	Unit Cost ($/1000 gpd/year) 0.5 MGD	1.0 MGD	5.0 MGD	10.0 MGD
0	466	545	679	573
2	466	518	446	391
4	466	487	367	333
6	466	415	329	302
8-20	466	370	305	285

Discussion. The data indicate that regional systems have higher costs at the beginning of the use period and lower costs at the end of the use period. The total costs over the use period is less for the larger regional systems.

Plants Phased - Existing Capacity

General . Assume that eight 0.5 MGD plants presently exist. New facilities are phased to meet the following capacity requirements:

Time	Capacity Required
0 years	4 MGD
2 years	4 MGD
4 years	6 MGD
6 years	8 MGD
8 years	10 MGD
10-20 years	10 MGD

Construction Schedules. The following construction schedules are utilized for plants:

Year	*20 at 0.5 MGD	10 at 1.0 MGD	2 at 5.0 MGD	1 at 10.0 MGD
0	0	8	2	1
2	0	0	0	0
4	4	2	0	0
6	4	0	0	0
8	4	0	0	0

* eight exist

The eight existing plants, together with their conveyance systems, are assumed to have a bonded indebtedness of $11,136,000 (seventy-five percent of 1975 cost). Each system is assumed to incur that debt.

Cost Data. Inflation is ignored in the cost analysis. Data are presented below:

	Unit Cost ($/1000 gpd/year)			
Year	0.5 MGD	1.0 MGD	5.0 MGD	10.0 MGD
0	391	624	525	470
2	391	624	525	470
4	418	539	418	384
6	429	453	367	343
8-20	436	401	336	316

Discussion. The data indicate that even in the case where regional systems must incur significant existing debt, long term cost incentives exist for regionalization.

Conclusions

The data presented above indicate that regional systems do have significant potential cost savings. These savings may be incurred in two ways:

- Allowing plants to treat at various levels.
- Allowing larger systems to be constructed.

In both cases central management is required. In the former, costs must be spread between service areas operating at different levels of effluent requirements. In the latter, centralized planning and an agency to build the system is necessary

One of the largest drawbacks of the regional systems is that they characteristically operate under capacity during the initial portion of the use period. This results in high treatment costs initially which are higher than nonregional systems. However, during the middle and end portion of the use period, costs are less for the regional systems. Thus, some mechanism to lower initial costs and raise later costs (in order to equitably spread costs among users) would be desirable.

TABLE C-1

COSTS FOR LEVEL 2 PLANT

	PLANT SIZE (MGD)			
NUMBER/ITEM	0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	640,000	900,000	2,700,000	4,400,000
2. Land Cost $	13,000	23,000	84,000	160,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	125,000	219,000	950,000	1,818,000
5. O & M Plant $/Yr.	34,000	70,000	165,000	240,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Costs $/Yr. Total Lines 4,5,6	163,000	298,000	1,159,000	2,145,000
8. Unit Cost ($/1000 gpd/year)	320	298	232	214

Note: 1975 costs. No conveyance costs for regionalizing.

TABLE C-2

COSTS FOR LEVEL 3 PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	840,000	1,100,000	3,200,000	5,200,000
2. Land Cost $	13,000	23,000	84,000	160,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	141,000	236,000	990,000	1,882,000
5. O & M Plant $/Yr.	64,000	80,000	190,000	280,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	209,000	325,000	1,224,000	2,249,000
8. Unit Costs ($/1000 gpd/year)	418	325	245	225

Note: 1975 costs. No conveyance costs for regionalizing.

TABLE C-3

COSTS FOR LEVEL 4 PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	960,000	1,250,000	3,600,000	5,800,000
2. Land Cost $	15,500	25,600	87,800	165,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	151,000	248,000	1,022,000	1,931,000
5. O & M Plant $/Yr.	74,000	92,000	240,000	350,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	229,000	349,000	1,306,000	2,368,000
8. Unit Cost ($/1000 gpd/year)	458	349	261	237

Note: 1975 costs. No conveyance costs for regionalizing.

TABLE C-4

COSTS FOR LEVEL 2N PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	940,000	1,200,000	3,500,000	5,500,000
2. Land Cost $	16,000	28,000	103,000	194,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	150,000	244,000	1,016,000	1,909,000
5. O & M Plant $/Yr.	80,000	100,000	240,000	350,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	234,000	353,000	1,300,000	2,346,000
8. Unit Cost ($/1000 gpd/year)	468	353	260	235

Note: 1975 costs. No conveyance costs for regionalization.

TABLE C-5

COSTS FOR LEVEL 3N PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	1,050,000	1,400,000	4,200,000	6,400,000
2. Land Cost $	16,000	28,000	103,000	194,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	158,000	260,000	1,072,000	1,982,000
5. O & M Plant $/Yr.	84,000	110,000	260,000	390,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	246,000	379,000	1,376,000	2,459,000
8. Unit Cost ($/1000 gpd/year)	492	379	275	246

Note: 1975 costs. No conveyance costs for regionalization.

TABLE C-6

COSTS FOR LEVEL 4N PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	1,250,000	1,600,000	4,250,000	7,000,000
2. Land Cost $	18,000	31,000	107,000	199,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	175,000	276,000	1,076,000	2,031,000
5. O & M Plant $/Yr.	94,000	120,000	300,000	450,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	273,000	405,000	1,420,000	2,568,000
8. Unit Cost ($/1000 gpd/year)	546	405	284	257

Note: 1975 costs. No conveyance costs for regionalization.

TABLE C-7

COSTS FOR LEVEL 3NP PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	1,150,000	1,530,000	4,400,000	6,800,000
2. Land Cost $	16,000	28,000	103,000	194,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	166,000	271,000	1,088,000	2,014,000
5. O & M Plant $/Yr.	107,000	146,000	396,000	630,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	277,000	426,000	1,528,000	2,731,000
8. Unit Cost ($/1000 gpd/year)	554	426	306	273

Note: 1975 costs. No conveyance costs for regionalization.

TABLE C-8

COSTS FOR LEVEL 4NP PLANT

NUMBER/ITEM	PLANT SIZE (MGD) 0.5	1.0	5.0	10.0
1. Total Capital Cost of Plant $	1,350,000	1,730,000	4,450,000	7,400,000
2. Land Cost $	18,000	31,000	107,000	199,000
3. Total Capital Cost of Collection $	900,000	1,800,000	9,000,000	18,000,000
4. Amortized Capital Cost $/Yr.	183,000	287,000	1,092,000	2,063,000
5. O & M Plant $/Yr.	117,000	156,000	436,000	690,000
6. O & M Sewer System $/Yr.	4,000	9,000	44,000	87,000
7. Total Annual Cost $/Yr. Total Lines 4,5,6	304,000	452,000	1,572,000	2,840,000
8. Unit Cost ($/1000 gpd/year)	608	452	314	284

Note: 1975 costs. No conveyance costs for regionalization.

TABLE C-9

COSTS FOR 2N PLANTS WITH VARIOUS DEGREES OF REGIONALIZATION

ALL PLANTS BUILT SIMULTANEOUSLY

NO FEDERAL PARTICIPATION

	PLANT SIZE (MGD)			
NUMBER/ITEM	0.5	1.0	5.0	10.0
1. Total Capital Cost of Conveyance $	-	150,000	1,840,000	4,020,000
2. Amortized Capital Cost of Conveyance $/Yr.	-	12,000	148,000	324,000
3. O & M Conveyance $/Yr.	-	7,000	78,000	173,000
4. Total Annual Cost of 2N Plant, Including Collection System (See Table C-4)	234,000	353,000	1,300,000	2,346,000
5. Total Annual Costs $/Yr. Total Lines 2, 3, 4	234,000	372,00	1,526,000	2,843,000
6. Unit Cost ($/1000 gpd/year)	468	372	305	284

TABLE C-10

COSTS FOR 2N PLANTS WITH VARIOUS DEGREES OF REGIONALIZATION

ALL PLANTS BUILT SIMULTANEOUSLY

FEDERAL PARTICIPATION

		PLANT SIZE (MGD)		
NUMBER/ITEM	0.5	1.0	5.0	10.0
1. Annual Cost Without Federal Participation $/Yr. (See Table C-4)	234,000	372,000	1,526,000	2,843,000
2. Federal Participation* $ Capital Cost	700,000	1,013,000	4,005,000	7,140,000
3. Amortized Federal Cost $/Yr.	56,000	82,000	323,000	575,000
4. Total Local Cost $/Yr. (1-3)	178,000	290,000	1,203,000	2,268,000
5. Unit Cost ($/1000 gpd/year)	356	290	240	227

* 75% of conveyance costs (Table C-9) and Plant Costs (Table C-4).

APPENDIX D

SAMPLE CALCULATIONS

APPENDIX D - SAMPLE CALCULATIONS

General

One portion of the alternative technical subplan evaluation involves a comparison of the estimated present worth costs. The assumptions involved in developing the cost information and the phasing of expenditures is presented in Chapter II. This appendix is designed to show the actual steps involved in developing the sewage treatment needs and a total present worth cost for a fictional drainage basin, Basin XYZ.

Develop Required Capacity

The following analysis of the raw data is performed to determine the future treatment plant capacity required in Basin XYZ.

1) The estimated population to be served by municipal treatment systems in 1995 is 40,000.

2) There are three existing treatment systems in the basin operating at effluent set 2 with the following data from the municipal inventory and projections.

System	Existing Population	Projected Population	Projected Flow (MGD)	Plant Capacity (MGD)
1	8,000	12,000	1.0	1.0
2	2,000	4,000	0.4	0.5
3	5,000	9,000	0.8	1.0

3) The difference between the projected populations in numbers 1 and 2 above is the projected population outside of existing service areas and equals 15,000 people.

4) Based on the assumption of 100 gpcd, the additional 15,000 people will generate 1.5 MGD of wateswater.

Locate Future Treatment Systems

Once the total treatment capacity for Basin XYZ is determined, the approximate location and number of individual plants is determined.

1) Based on the municipal projections, all three existing plants will remain throughout the planning period.

2) Based on the projected land use, the 15,000 people not in existing service areas, will evolve around two major locations. The split is estimated at 10,000 and 5,000.

3) Based on the above, two new treatment systems will be required, one at 1.0 MGD and the other at 0.5 MGD.

4) Therefore, a total of five treatment systems are projected in Basin XYZ by 1995.

Determine Water Quality

Once the number of treatment systems and their respective discharge locations are determined, the water quality of the receiving stream segment is simulated via computer modeling techniques. Based on the results of the water quality simulation model, all treatment systems are required to achieve effluent set 2N. Therefore, the existing treatment plant will require upgrading, i.e., the addition of nitrification facilities, and all new plants will be designed and constructed as a secondary activated sludge plant with nitrification facilities.

Develop Cost Data

Cost requirements to provide the necessary sewage treatment plant facilities are tabulated for each plant as shown on work sheets D-W1 through D-W5. The treatment plant costs are derived from the Point Source Analysis cost curves. The collection system costs are developed by Roy F. Weston, Inc., based on EPA information. The costs associated with collection systems are obtained as follows:

a) Existing O & M costs are estimated at $0.87/capita/year for the served population.

b) Capital costs are estimated at $180/capita for the additional population projected for the service area.

These cost estimates have been included on the treatment plant work sheets. All costs are then summarized on work sheet D-W6.

Develop Present Worth Cost Estimates

Once the annual O & M and the capital costs have been identified, the assumptions involved in phasing the expenditures come into play. The assumptions are listed in Chapter II. The present worth analysis is performed on work sheet D-W7.

The results indicate that the total present worth cost to provide the required level of sewage treatment in Basin XYZ is approximately $8.3 million. About 45 percent of the total present worth cost is due to operational and maintenance expenditures with the remainder being a result of capital expenditures.

Regionalization Concept

An alternative to building additional sewage treatment facilities for Basin XYZ is to construct a single large treatment facility, transport the wastewater from the other service areas, and abandon the remaining unused facilities. The following evaluation of data occurs for the regional treatment system:

1) The same amount of wastewater will be generated from the areas identified in the nonregional alternative, 3.7 MGD.

2) The same level of treatment will be required in the basin (2N).

3) The same wastewater collection system will be required for each service area.

4) The two new treatment plants projected for the non-regional case will not be built, and two of the three existing treatment plants will be abandoned. The remaining treatment plant will become the regional facility and will be upgraded and expanded.

5) Wastewater from the four other areas will be transported to the regional plant via force main.

Develop Cost Data

The following assumptions were made for the regional alternative:

1) The regional system will be built in 1983.

2) The two existing plants that are to be abandoned will be abandoned in 1983. They will not be upgraded from treatment level 2 to 2N.

3) The two new population clusters that were to receive municipal treatment plants under the nonregional concept, will not be provided sewage treatment services until 1983 when the regional system is in operation.

4) The site of the regional system will be at the location of the existing 1.0 MGD treatment plant identified as STP #3.

5) The cost of expanding the existing 1.0 MGD plant to 3.7 MGD is equal to the cost of a new 2.7 MGD plant.

Force main transporation costs are obtained from the Point Source Analysis cost curves. In Basin XYZ the following flows must be transported to the regional system:

Service Area	Flow (MGD)	Distance (Miles)
STP #1	1.0	3
STP #2	0.4	6
Projected (#4)	1.0	10
Projected (#5)	0.5	13

Work sheets D-W8 through D-W12 present the estimated costs for each of the areas to be served. Work sheet D-W13 is a summary of the regional concept costs.

Develop Present Worth Cost Estimates

The timing of new construction and the abandoning of existing treatment plants previously discussed is used for phasing the total expenditures as shown on work sheet D-W14.

The results of the analysis indicate a total present worth cost to Basin XYZ for a regional treatment plant to be approximately $9.4 million.

Conclusion

The present worth cost evaluation of regionalization alternatives resulted in the following:

	Present Worth in Million Dollars		
Alternative	O & M	Capital	Total
Nonregional	3.7	4.6	8.3
Regional	2.9	6.5	9.4

Although a significant saving in Operation and Maintenance costs can be obtained from a regional system, the capital costs involved in transportation make the regional system uneconomical.

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☒ UPGRADE STP #1
EXISTING CAPACITY: 1.0 MGD
EXISTING TREATMENT LEVEL Z PROJECTED TREATMENT LEVEL ZN

WORK SHEET
D-W1

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					70,000		
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification					30,000		350,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					7,000		
FUTURE					10,500		720,000
TOTAL							

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☒ UPGRADE STP #2
EXISTING CAPACITY: 0.5 MGD
EXISTING TREATMENT LEVEL 2 PROJECTED TREATMENT LEVEL 2N

WORK SHEET
D-W2

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					57,000		
Chem. Sed. (3)3040/MGD							
Filtration (4)							
Nitrification					22,000		310,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
Collection System							
Existing					1,700		
Future					3,500		360,000
TOTAL							

WORK SHEET
D-W3

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☒ UPGRADE STP # 3
EXISTING CAPACITY: 1.0 MGD
EXISTING TREATMENT LEVEL 2 PROJECTED TREATMENT LEVEL 2N

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					70,000		
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification					30,000		350,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					4,400		
FUTURE					7800		720,000
TOTAL							

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☒ NEW PLANT 1.0 MGD/ ☐ UPGRADE STP # 4
EXISTING CAPACITY: - MGD
EXISTING TREATMENT LEVEL - PROJECTED TREATMENT LEVEL 2N

WORK SHEET
D-W4

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					70,000		900,000
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification					30,000		350,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					-		
FUTURE					8,700		1,800,000
TOTAL							

SEGMENT NAME: XYZ

TYPE COST ESTIMATE: ☒ NEW PLANT 0.5 MGD/ ☐ UPGRADE STP #5

EXISTING CAPACITY: - MGD

EXISTING TREATMENT LEVEL - PROJECTED TREATMENT LEVEL 2N

WORK SHEET
D-W5

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.		0.5			57,000		640,000
Chem. Sed. (3)3040/MGD							
Filtration (4)							
Nitrification					22,000		310,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					-		
FUTURE					4400		900,000
TOTAL							

WORK SHEET
D-W6

BASIN XYZ NONREGIONAL

				EXISTING FACILITY COSTS						NEW FACILITY COSTS					
STP #	EXIST CAP /LEVEL OF TREATMENT	ULTIMATE REQUIRE. (MGD)	FUTURE FACILITIES (MGD)	EXISTING ELECTRICAL (KWH/YR)	EXISTING O&M ($/YR)	UPGRADING CAPITAL ($)	UPGRADING O&M ($/YR)	UPGRADING ELECTRICAL (KWH/YR)	UPGRADING LAND (ACRES)	COSTING SIZE (MGD)	CAPITAL COST ($)	O&M COST ($/YR)	ELECTRICAL REQUIRE. (KWH/YR)	LAND REQUIRE. (ACRES)	LEVEL OF TREATMENT
1	1.0/2	1.0	1.0/2N		70,000	360,000	30,000								
	Collection		SYST		7,000						720,000	10,500			
2	0.5/2	0.5	0.5/2N		57,000	310,000	22,000								
	Collection		SYST		1,700						360,000	3,500			
3	1.0/2	1.0	1.0/2N		70,000	350,000	30,000								
	Collection		SYST		4,400						720,000	7,800			
4	-	1.0	1.0/2N		-	-	-			1.0	1,250,000	100,000			
	Collection		SYST		-						1,800,000	8,700			
5	-	0.5	0.5/2N		-	-	-			0.5	950,000	79,000			
	Collection		SYST.		-						900,000	4,400			
		TOTAL													
		TREATMENT			197,000	1,010,000	88,000				2,200,000	179,000			
		COLLECTION			13,100	-	-				4,500,000	34,900			

FORM 441

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BY __________ DATE __________ WESTON SHEET D-W7 OF ______

CHKD BY ______ DATE __________ W.O. NO. __________

PROJECT __________

SUBJECT PRESENT WORTH ANALYSIS - NONREGIONAL

PRESENT WORTH - O&M EXPENSE

	1977-1983	1984-1990	1991-1995
EXISTING - PLANT	197,000	197,000	197,000
- Collection	13,100	13,100	13,100
UPGRADING - PLANT	-	88,000	88,000
NEW FAC. - PLANT[1]	(7/38) 33,000	(21/38) 99,000	(33/38) 155,000
- Collection[1]	4,000	12,000	19,000
TOTAL	247,100	409,100	472,100
BRING TO BEG. OF PERIOD	x 5.56	x 5.56	x 4.2
BRING TO 1977 WORTH	x 1.0	x 0.66	x 0.44
SUB-TOTALS	1,374,000	1,501,000	872,000

TOTAL PRESENT WORTH OF O&M = $3,747,000

PRESENT WORTH - CAPITAL EXPENSE

NEW PLANT[2]	116,000	116,000	116,000
NEW COLLECTION[2]	237,000	237,000	237,000
TOTAL	353,000	353,000	353,000
	x 5.56	x 5.56	x 4.2
	x 1.0	x 0.66	x 0.44
SUB TOTAL	1,963,000	1,295,000	652,000

UPGRADING CAPITAL 1,010,000 x 0.66 = 667,000

TOTAL PRESENT WORTH CAPITAL = $4,577,000

1. ASSUMES UNIFORM INCREASE IN NEW FACILITY O&M DURING PERIOD
2. ASSUMES UNIFORM EXPENDITURE OF NEW FACILITIES DURING PERIOD

12/77

RFW. 231-9-68

WORK SHEET
D-W8

STP*1

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☐ UPGRADE
EXISTING CAPACITY: 1.0 MGD
EXISTING TREATMENT LEVEL 2 PROJECTED TREATMENT LEVEL (ABANDON 1983)

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					70,000		
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification							
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					7,000		
FUTURE					10,500		720,000
TRANSPORTATION							
EXISTING PUMP STATION					9000		-
FORCE MAIN					600		276,000
TOTAL							

WORK SHEET
D-W9

SEGMENT NAME: XYZ STP#2
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☐ UPGRADE
EXISTING CAPACITY: 0.5 MGD
EXISTING TREATMENT LEVEL 2 PROJECTED TREATMENT LEVEL (ABANDON 1983)

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					57,000		
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification							
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					1,700		
FUTURE					3,500		360,000
TRANSPORTATION							
EXISTING PUMP STATION					6,500		–
NEW PUMP STATION					6,500		80,000
FORCE MAIN					1,000		483,000
TOTAL							

STP#3

WORK SHEET
D-W10-A

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☒ UPGRADE-ENLARGE
EXISTING CAPACITY: 1.0 MGD
EXISTING TREATMENT LEVEL 2 PROJECTED TREATMENT LEVEL 2N

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.					70,000		
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification					30,000		350,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
Collection System							
Existing					4,400		
Future					7,800		720,000
TOTAL							

STP #3

WORK SHEET
D-W10-B

SEGMENT NAME: XYZ

TYPE COST ESTIMATE: ☒ NEW PLANT 2.7 MGD/ ☐ UPGRADE

EXISTING CAPACITY: ______ MGD

EXISTING TREATMENT LEVEL – PROJECTED TREATMENT LEVEL 2N

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap.	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.	3.7	2.7			140,000		1,500,000
Chem. Sed. (3)3040/MGD							
Filtration (4)							
Nitrification	3.7	2.7			70,000		500,000
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM	(SEE WORK SHEET D-W10-A)						
TOTAL							

PROJECTED #4

WORK SHEET
D-W11

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☐ UPGRADE
EXISTING CAPACITY: 1.0 MGD
EXISTING TREATMENT LEVEL ______ PROJECTED TREATMENT LEVEL (TRANSPORT)

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.							
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification							
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					-		
FUTURE					8,700		1,800,000
TRANSPORTATION							
NEW PUMP STATION					9,000		140,000
NEW PUMP STATION					9,000		140,000
NEW PUMP STATION					9,000		140,000
FORCE MAIN					2,000		920,000
TOTAL							

PROJECTED #5

WORK SHEET
D-W12

SEGMENT NAME: XYZ
TYPE COST ESTIMATE: ☐ NEW PLANT ______ MGD/ ☐ UPGRADE
EXISTING CAPACITY: 0.5 MGD
EXISTING TREATMENT LEVEL ______ PROJECTED TREATMENT LEVEL (TRANSPORT)

Unit Process	Capacity MGD		Operating Costs			Capital Costs	
	O&M	Cap	Elect. (KWH/Yr.)	Chem. (TOTAL)	O&M $/year	Land (acres)	Capital ($)
Standard Level 2 Treat.							
Chem. Sed. (3) 3040/MGD							
Filtration (4)							
Nitrification							
Post Aeration							
Phos. Re. 1330/MGD							
Land Disposal							
COLLECTION SYSTEM							
EXISTING					-		
FUTURE					4,400		900,000
TRANSPORTATION							
NEW PUMP STATION					6,500		80,000
NEW PUMP STATION					6,500		80,000
NEW PUMP STATION					6,500		80,000
FORCE MAIN					2,100		1,047,000
TOTAL							

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BASIN XYZ REGIONAL

WORK SHEET
D-W/13

				EXISTING FACILITY COSTS						NEW FACILITY COSTS					
SEEU. AREA No.	EXIST. CAP /LEVEL OF TREATMENT	ULTIMATE REQUIRE. (MGD)	FUTURE FACILITIES (MGD)	EXISTING ELECTRICAL (KWH/YR)	EXISTING O&M ($/YR)	UPGRADING CAPITAL ($)	UPGRADING O&M ($/YR)	UPGRADING ELECTRICAL (KWH/YR)	UPGRADING LAND (ACRES)	COSTING SIZE (MGD)	CAPITAL COST ($)	O&M COST ($/YR)	ELECTRICAL REQUIRE. (KWH/YR)	LAND REQUIRE. (ACRES)	LEVEL OF TREATMENT
1	1.0/2	–	–		70,000	–	–				276,000	9,600			
	COLLECTION SYSTEM				7,000										
											720,000	10,500			
2	0.5/2	–	–		57,000	–	–								
	Collection SYSTEM				1,700						563,000	14,000			
											360,000	3,500			
3	1.0/2	3.7	1.0/2N		70,000	350,000	30,000								
			2.7/2N												
	Collection System				4,400						2,000,000	210,000			
											720,000	7,800			
4	–	–	–												
	Collection SYSTEM										1,340,000	29,000			
											1,800,000	8,700			
5	–	–	–												
	Collection SYSTEM										1,287,000	21,600			
											900,000	4,400			
		TOTALS													
TRANSPORT + TREATMENT					197,000	350,000	30,000				5,466,000	284,200			
		Collection			13,100	-	-				4,500,000	34,900			

FORM 441

WESTON
ENVIRONMENTAL CONSULTANTS-DESIGNERS

BY ________ DATE ________ SHEET D-W14 OF ________
CHKD BY ________ DATE ________ W.O. NO. ________
PROJECT ________
SUBJECT PRESENT WORTH ANALYSIS - REGIONAL

PRESENT WORTH - O&M EXPENSE

		1977-1983		1984-1990		1991-1995
EXISTING-PLANT		197,000		–		–
-Collection		13,100		13,100		13,100
REGIONAL PLANT		–		284,200		284,200
NEW COLLECTION	(7/38)	4,000	(21/38)	12,000	(33/38)	19,000
TOTAL		214,100		309,300		309,300
BRING TO BEG OF PERIOD		x 5.56		x 5.56		x 4.2
BRING TO 1977 WORTH		x 1.0		x .66		x .44
SUB TOTALS		1,190,000		1,135,000		572,000

TOTAL PRESENT WORTH OF O&M = $2,897,000

PRESENT WORTH - CAPITAL EXPENSE

REGIONAL PLANT = $5,466,000 x 0.66 = $3,608,000
UPGRADING = 350,000 x 0.66 = 231,000

		77-83		84-90		91-95
COLLECTION SYSTEM	(1/19)	237,000	(1/19)	237,000	(1/19)	231,000
		x 5.56		x 5.56		x 4.2
		x 1.0		x 0.66		x 0.44
SUB TOTAL		1,318,000		870,000		438,000

TOTAL PRESENT WORTH - CAPITAL = 6,465,000

12/77

APPENDIX E

ENVIRONMENTAL CONSIDERATIONS RELATIVE TO DRY AND WET WEATHER WATER QUALITY STANDARDS

APPENDIX E - ENVIRONMENTAL CONSIDERATIONS RELATIVE TO DRY AND WET WEATHER WATER QUALITY STANDARDS

Introduction

In cases where the technical subplans produce significantly differing levels of dissolved oxygen or fecal coliform, the effect of the differing levels on the aquatic habitat will be presented. The assessment of differing levels of dissolved oxygen and fecal coliform will be approached for the total 208 Planning Area. This total approach is made possible by the homogeneity of aquatic species; and the similarities of stream substrate and fish forage within the Planning Area.

Dissolved Oxygen

Probably the most influential factor in maintaining a fishable condition in a stream segment is the level of dissolved oxygen. The United States Bureau of Fisheries[1] and Scripps Oceanic Institute[2], both agreed in independent studies that a minimum dissolved oxygen level of 5.0 mg/l will support and propogate most freshwater species of fish. Considering the data from other reliable sources particularly from field studies, 5 mg/l seems the lowest value which may reasonably be expected to maintain a varied fish fauna in good condition.

Experimental evidence has shown that most fish on occasion can tolerate for a period of hours or even days, water containing less than 5 mg/l dissolved oxygen. This is very applicable to wet weather conditions in some of the 208 stream segments. In these segments wet weather flushes a higher concentration of oxygen demanding organics into the stream. The increased biological oxygen demand (BOD) causes a depression in dissolved oxygen below the 5.0 mg/l level in the immediate area. This localized depression normally does not merit concern if sufficient dissolved oxygen remains up and downstream. Research substantiates that fish in the depressed segment will migrate to more favorable conditions with little ill effect. But, once the stream has returned to steady-state conditions and the dissolved oxygen returns to normal, the fish will return.

The dissolved oxygen content of streams normally varies with at least four major sets of factors: (1) physical conditions such as stream flow and temperature, (2) oxygen produced by aquatic plants, (3) oxygen consumed by respiring organisms and (4) oxygen demand of natural or manmade organics. When dissolved oxygen concentrations of 5 mg/l or greater are maintained with other favorable factors, the stream will support a mixed fish fauna.

Certainly fish eggs and juvenile fish are much more susceptible to depressions in dissolved oxygen, since it is generally impossible for them to migrate to more favorable conditions.

The spring spawning season can be a critical time for fish species if dissolved oxygen concentrations are not maintained at very high levels. If spring rains flush high concentrations of oxygen demanding organics into the stream, serious adverse impacts may occur.

For the purposes of comparison, a mixed fish fauna is defined as fauna including representatives of the following families: Centrarchidae - largemouth bass, spotted bass, crappie, and sunfish; Percidae - perch; Lepisosteidae - alligator gar, spotted gar and longnose gar; Ictaluridae - channel catfish, blue catfish, and black bullhead; Catostomidae - river carpsucker, smallmouth buffalo, and spotted sucker. Associated with higher dissolved oxygen levels would be a myriad of support and forage organisms belonging to: Crustacea - grass shrimp, blue crab; Pelecypoda - clams and mussels; Insecta - stonefly.

When stream dissolved oxygen concentrations chronically approaches a level of 4 mg/l or less, the fish diversity switches away from the dominant gamefish such as bass and crappie; to the more resistant rough fish such as gar, sucker and buffalo. Concurrent with the shift toward the rough species of fish the bottom fauna also undergoes a shift towards more oxygen tolerant species such as tubifex worms and chironomid. Depressed oxygen levels influence the spawning habits of the bass family, and retards proper embryonic development.

If stream conditions permit the dissolved oxygen to remain chronically below 2.0 mg/l even the most resistant fish will migrate to more favorable stream segments or die of oxygen starvation. The following table summarizes dissolved oxygen and expected fish habitat.

TABLE E-1
OXYGEN REQUIREMENTS OF FISH

Dissolved Oxygen (mg/l)	Expected Fish Habitat
5.0 or greater	mixed fish habitat - bass, crappie sunfish
5.0 - 3.0	rough fish predominate - gar, sucker, buffalo
2.0 or below	death of most fish species

Suspended Solids

Coinciding with the oxygen demanding organics is stream turbidity caused by the suspended solids. Most suspended solids are natural in origin caused by stream erosion, sloughing of banks, and runoff. Some suspended solids are manmade, either point sources such as sewage treatment or nonpoint sources such as farming and construction. Continual high suspended solids will, over a long period of time, influence the rate of photosynthesis and resultant productivity. A decrease in productivity, if serious enough, would affect the number and kind of fish present in a stream.

Fecal Coliform

Other beneficial water uses, noncontact recreation, swimming and bathing do not require such stringent dissolved oxygen requirements as do the propagation of fish.

In determining other beneficial uses of a stream, swimming, bathing and public health are paramount. The particular items of most importance in determining the suitability of water for contact recreation, domestic supplies and public health is freedom from concentrations of pathogens which cause illness to human beings. A measure or indicator of pathogens is based chiefly upon the bacteriological quality as measured by the density of coliform bacteria. Coliform bacteria are found in the intestine of man and could therefore serve as an indicator of the presence of potentially pathogenic organisms.

For certain water uses maximum permissible coliform limits are specified. Concentration in excess of these limits are cause to reject the water for that use. Following are some recommended stream coliform limits for specific water uses:[4]

1) Raw Water Supply
   Total coliform content shall not exceed 100/100 ml and fecal coliform content 20/100 ml. The monthly arithmetic averages should not exceed 10,000/100 ml total coliform or 2,000/100 ml fecal coliform.

2) Contact Recreation
   Fecal coliform not to exceed 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.

3) Shellfish Waters
   Total coliform median MPN not to exceed 70/100 ml.

The low coliform limits on shell fish is based on their filter feeding habits, and their ability to concentrate in body tissue fecal coliform levels six times higher than ambient levels in the surrounding water.

Conclusions

1) 5.0 mg/l dissolved oxygen, recommended dry weather standard only to be exceeded for short periods of time.

2) 4.0 mg/l dissolved oxygen, recommended wet weather standard, duration to be determined on an individual basis for each segment.

References

(1) Ellis, M.M., 1935, "Water Purity Standards For Freshwater Fishes - - Special Report", U.S. Bur. Fish., pp 1-14, Washington.

(2) Keys, A.B., 1930, "Influence of Varying Oxygen Tension upon the Rate of Oxygen Consumption of Fishes", Bull. Scripps Inst. Ocean., Technical Series, vol. 2, pp. 307-317, La Jolla, Calif.

(3) Biology of Water Pollution, U.S. Department of the Interior, Federal Water Pollution Control Administration, 1967.

(4) Texas Water Quality Standards, Texas Water Quality Board, October 1973.